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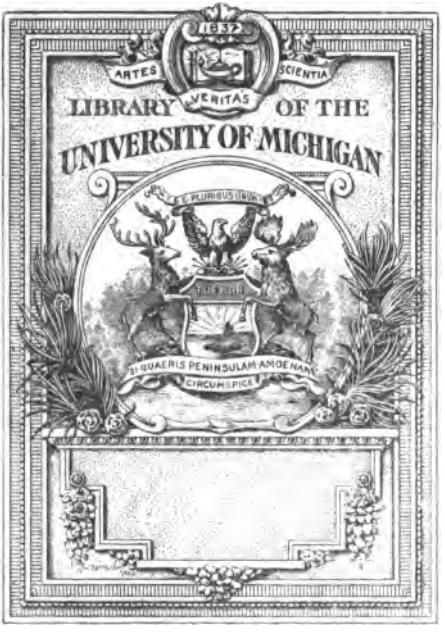
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UNIT PHOTOGRAPHY

UNIT PHOTOGRAPHY

BY

FRANK MORRIS STEADMAN

AUTHOR OF "HOME PORTRAITURE," ETC.

13 Plates. 10 Illustrations.

NEW YORK

D. VAN NOSTRAND COMPANY

25 Park Place

1914

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PREFACE

AS a matter of record the author desires to state that the idea of the unit of convergence or cone unit came to him about the year 1895 while working at his business of home portraiture and was suggested by a plan to admit as nearly as possible the same volume of light from ordinary windows which in different homes varied greatly in width. It was conceived that by placing the subject so that the head should be in the room opposite one of the window casings and at a distance *from the outside of the wall* equal to the width of the window, the geometrical form of the beam of light illuminating the head would be the same, regardless of the width of the window and also of the thickness of the wall. On closing the window with a dark cloth from the level of the head down and adjusting the window shade so that the effective opening is square this form is seen to be that defined by one quarter of one side of a cube in its relation to the center of the cube, where the head is supposed to be located. This leaves the sky intensity as the only variable element of the light source.

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From this idea came that of the rationality of considering a convergent form as a fundamental element in the calculation of the photographic energy of light and lighted surfaces and from these considerations the present system has resulted.

A desirable name for this cone unit has been difficult to decide upon and the author invites suggestions in naming it.

Should the present method prove valuable and fill the gap which now exists between the schools and the practice of photography the author would recommend a union of effort on the part of photographic societies and all interested with the view of deciding upon an international standard tinting medium for the measurement of actinicity in units by the $F/1$ method.

The author wishes to offer here a humble tribute to the memory of the late Professor George W. Barker for his earnest words of appreciation, prophecy, and encouragement relative to the present method of calculating problems in light and to the adaptability of the method to popular education. Thanks are especially due to Dr. Arthur W. Goodspeed, Professor of Physics of the University of Pennsylvania, for the advance use of the present method, while yet in manuscript, in class work in the university

and for his earnest co-operation in the arrangement of the subject matter as it appears in this book.

Due acknowledgments are made to the G. Cramer Dry Plate Company and to the company of Lumière et Fils for special assistance of various kinds.

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UNIT PHOTOGRAPHY

CHAPTER I

INTRODUCTION

PURPOSE OF THE BOOK

THIS book is written with a desire to establish a rational scientific foundation for the practice of photography and for the study of light as it is daily observed in nature. My first duty therefore is to establish the fact that such a foundation is lacking at the present time.

It will be shown that the chemical energy of light, the relative aperture of a lens, and the degree of sensitiveness of photographic emulsions, which are the fundamental elements in photography, are at present lacking simple units of measurement. It is maintained that this alone is ample proof that photography is not now scientifically practised.

In various elementary books are to be found tables of length, mass, time, etc., and also an explanation of the scales for indicating temperature as well as the usual method of dividing the arc of a circle into degrees or other units in

order to measure plane angles. There is however little if any reference to the measure of a *solid angle* by the part of a spherical surface subtending it.

Should a teacher, even of science, desire at the present time to take up the practice of photography, he must do so with the same uncertainty as one of his younger pupils. There is nothing in the books to enable him to predetermine an exposure as the result of a direct numerical relation between the actinic property of the light emitted by a surface to be photographed, the relative aperture of the lens and the sensitiveness of the emulsion used. It will be the author's duty to show that the time of photographic exposure in any given case is a simple function of these three quantities.

The great majority of professional photographers are strongly prejudiced against any measurement of light in their practice. They insist that the photographic strength of the light may be *seen* and that the ability to judge exposures correctly is a reason for professional pride. By his experience the professional develops a sort of *feeling* that a certain time in each particular case in hand is the correct exposure. This feeling is a form of involuntary mental action which is brought about by daily experience under usual conditions of plate, light and lens diaphragm and the varying conditions of the subject, time of day, etc.

It can readily be seen that the endeavor to reduce all these elements at a glance (as the professional photographer is usually obliged to do), to a mental impression or to a "feeling" is in the first place extremely unscientific and in the second place to do so with even approximate exactness is impossible, except by long experience with different classes of work such as "viewing," interiors, and portraiture. Even the most experienced workmen err seriously when for example the light is for temporary reasons much below the intensity on clear days and there is no photographer but may recall such errors in his own experience.

Being based on measurable elements the *process* of photography should be considered, as a *craft* merely, and in order that the mind may act with certainty all quantities should be measured and expressed in simple unit terms. This will make possible a more uniform product for the artisan as well as place in the hands of the artistically inclined that freedom of technique which can only be obtained through a perfect knowledge of his tools by much practice.

To drop for a moment to the ridiculous, the following two imaginary letters of self-recommendation should illustrate clearly the irrational standard which is set up for photography:

Mr. X,

Dear Sir, — I am informed that you are looking or a workman and write to offer my services,

being desirous of filling a position more in harmony with my ability than the one I now hold. I have had twelve years active experience in portraiture, viewing, and other branches of the business and pride myself especially on the correctness of my exposures which are so accurate that a plate is seldom lost. I use no device for measuring the light but depend entirely on my judgment which has been greatly refined during these years of practice.

I have my own methods of development by which I am able to exercise great control in developing under- and over-exposed plates and also an especially effective intensifier for increasing the opacity of those which after development are found to be too thin to make good prints.

I would be willing to begin to work without a stated salary so that I may prove that I am not trying to misrepresent myself to you in this letter.

Hoping to hear from you favorably, etc.,

A. B.

It may easily be imagined that the man was hired and that he proved satisfactory according to the accepted standards. The letter which follows is written from exactly the same point of view and is no more ridiculous than the one already given:

Mr. Y,

Dear Sir, — I understand that you need a carpenter and write to say that I have had many

years experience including many branches of the work. This experience has developed a very accurate judgment of distance and angle and I can saw a board square or at any desired angle or bevel without the use of any measuring tools whatever. I can estimate distance so accurately that in sawing boards or timbers to length one is seldom spoiled. Should it be somewhat too long for the place in which it is designed to fit, it can of course be shortened by sawing it off again. Should it on the contrary prove too short I have my own method of lengthening it by splicing.

I can also draw or cut out when necessary a sufficiently true circle, square, or other form, without the use of the usual tools and have always felt that this freedom from exact measurements and independence of mechanical means for securing results has had a great influence in developing my taste and stamping my work with an unmistakable individuality.

I should be glad of an opportunity to prove my ability as above stated and hope to hear from you favorably. Yours, etc.,

C. D.

It would be difficult to imagine that this man "heard favorably." The two letters show that the prevailing mental attitude toward exact measurements in the two crafts of photography and carpentry differ to an almost inexplicable degree.

A man who by years of experience and the spoiling of a vast amount of good material finally arrives at a point where he is able to estimate rather closely a required exposure, should be able to see the error of his position when he finds that a novice with a few days practice in learning to use a measure is able to expose with still more exactness than he, and under more varied conditions of light. The use of a measure is not difficult to learn and as measuring is more exact than estimating, the superiority of the former method cannot be denied, especially as we are here dealing with quantitative elements.

The writer has pressed this point somewhat in order to leave no doubt in the mind of the reader that photography is now practised in the most unscientific and irrational manner by the majority of workers.

It is important that professional photographers become more adept in the practice of portraiture in the homes of their clients. The demand for this class of work is increasing year by year and the great variety of light conditions encountered make the measurement of the light the only rational guide to exposure.

One who does not advance in the knowledge of his chosen work and in the ability to do that work must be content to see others excel him through learning the newer and more advanced methods as they are developed. It is of still greater importance however that the desire for

advancement or the *spirit of growth* be not dwarfed by holding to ideas and methods whose error has been proven by advancement.

ANALYSIS OF PRESENT CONDITIONS

In order to comprehend fully the chaotic condition of photographic practice at the point where the novice commences to work it will be desirable to examine into his methods and results. In the first place, through the lack of the needed elementary knowledge which because of its nature and importance should be taught in the elementary arithmetic, the beginner takes up photography with no knowledge of the photographic intensity of light, the diaphragms of his lens, the speed of the plate or film he is to use. Neither is he taught to estimate time correctly by counting nor the importance of time in photographic work. In his practice he may find on a box of plates a sign or name similar to the following, which in itself signifies nothing whatever as to the actual speed of the plate: "Rocket," "Meteor," "XXXXX," "27," etc. Almost without exception the numbers on the lens which indicate the diaphragms have in his mind no mathematical significance, and on looking over the directions for exposing he may find the following terms indicative of light intensities or conditions: "Bright sunshine," "dull sunshine," "cloudy bright," "cloudy," "cloudy dull," and "very cloudy." The natural

result is that the beginner is completely at sea, having no exact knowledge whatever. He usually indulges in a short season of reckless "shooting" at almost everything within range, but tiring early of his failures the camera is laid aside to wait another period of animation in the more or less distant future.

There are two possible exceptions to this rule. The most common is when the beginner finds that his failures are those in which he has tried to estimate time exposures under light conditions of his own selecting, and that his successes or usable negatives have resulted from "snap shots" in sunlight. On observing the above many workers begin to make snap shots in sunlight to the exclusion of interiors, portraits, and the many other subjects which should interest them. Although in this way a high percentage of usable negatives may be secured this is seen to be due solely to the limitation of the subjects attempted. What is required is the knowledge to do work with exactness under all conditions. The second class of exceptions to the general rule comprises those who endeavor diligently to discover the cause of the failures and in so doing arrive at some degree of ability and certainty.

Those who make a practice of having their films developed by others, including many of the snap shot class above mentioned, are found to suffer a total loss of between *seventy* and

Plate I—DEMURE

eighty per cent of their exposures. This was ascertained by the author by referring to a register of such work which showed a total loss of *seventy-nine* per cent. Those who develop for amateurs know how frequently whole rolls of film come through without a single usable negative.

Such a state of affairs is thought by the author to be inexcusable in this day of scientific advancement and he hopes by a method to be presented to establish a new standard of simplicity in photographic practice which may be utilized by the many and which will be of such a nature as to demand the attention of educators and in time find its true place in the elementary books of instruction in the schools. All the common schools cannot of course take up the *practice* of photography, but the simple units of measurement of light cones and of their photographic intensity, at least may be incorporated in the list of other units and tables in the elementary books. This with accompanying problems and their solutions would prepare the pupil for the practice of photography by imparting a fundamental knowledge of light as it works in nature. This study properly developed, could be made influential in developing the artistic observation of the pupil for the reason that nearly all the causes of photographic contrast are also causes of visible light and shade effects.

CHARACTER OF PHOTOGRAPHIC EMULSIONS

A somewhat general discussion of the properties of photographic emulsions, as their *speed*, latitude, etc., is deemed advisable here. The makers of dry plates and films with but very few exceptions do not place on the packages containing their products any numerical sign indicating the sensitiveness of those products. The author believes that the methods employed to indicate by numbers the speeds of emulsions are open to the objection that the numbers resulting are of a character difficult to associate with the popular conception of the quality of "speed." Thus, it is said of a certain trotter —"her speed is two-six," meaning in the popular mind that the horse can trot a mile in two minutes and six seconds. The horse travels one mile in a certain time, less or greater as it is *faster* or *slower;* in other words the speed is the ratio of the distance traveled to the time required.

The above popular manner of indicating speed in time units is adopted by the author for marking the speed of emulsions. Thus, if a definite change is brought about on a certain plate in *one minute* under known fixed conditions, then the speed of that plate may be said to be "one minute," while a slower one might require two or four minutes or a faster one but a half or quarter minute to suffer the same change. But

the known fixed work that must be done upon a plate in order to ascertain the speed of its emulsion in simple time units must be as simple in character as the time units themselves, in fact that work must be exactly the same in character as the effect brought about in recording a picture in ordinary practice. In point of fact the method to be described is of such a nature that each exposure of an emulsion in ordinary practice is a practical test and proof of the speed of the plate or film used.

Those who publish speed lists have deemed it necessary to differentiate the speeds of emulsions in steps varying as little as twenty-five per cent, notwithstanding the average emulsion on the market has a practical latitude of more than *four hundred* per cent. That is to say, should a plate under certain conditions experience what might be termed an exact normal exposure, in one second, an exposure of one half second and also one of two seconds would be entirely within the limits of correct exposure to a degree satisfactory to the most careful critic. Furthermore even this approach to what might be termed the normal time of exposure is much closer, except in rare cases, than can be made by any one who simply estimates the conditions.

Again should a worker desire under certain conditions to produce a so-called perfect or normal negative, another with less detail in the shadows and still another with greater softness,

"atmosphere," or half-tone effect, he could in certain cases, if he be familiar with the character of emulsions, give on the one hand a quarter of the normal exposure and on the other four times that exposure without carrying to an undue extreme the desired characteristic effect in the resulting negative. Should he go to only one half the above extreme and give on one side, half, and on the other, double the normal exposure mentioned above, he would obtain a *just well perceivable step* in the direction of the characteristic quality sought. It is evidently irrational to define any measurement to a degree unnecessary in the uses to which it may be put and for this reason, only steps which vary to the extent of one hundred per cent are fixed by the author and each emulsion is given the speed time number in such a series which is nearest its actual speed. Even so this method provides for a refinement of *fifty* and not one hundred per cent since it may be seen that the actual or theoretical speed could only drop at most, half way between two of the fixed steps above mentioned. In the nature of the case or by the law of averages the great majority of emulsions would be much closer than this to one of the fixed intervals in the speed scale.

Furthermore should a certain plate show on actual test a speed of three minutes its speed time could be considered as either two or four minutes and in deciding which of these two

speeds to give it there should be considered what may be termed the *endurance* of the emulsion. This is the amount of exposure the emulsion will *endure* and still render in the most exposed area, clearly or without fog, the texture of a surface photographed. This quality of endurance lies at one end of the latitude of an emulsion and in practice it is of even more importance than its mere speed. (Fig. 9, p. 109, and p. 118 in Chap. viii.)

Should the above plate with a supposed test speed of three minutes show by a four minute exposure a clear and unveiled texture of the surface photographed, it would be a greater compliment to the emulsion and its manufacturer to call its speed four rather than two minutes for although the longer time would indicate a slower emulsion it would also indicate greater endurance and latitude. In any case the author deems that measurements with a smaller limit of error than that herein adopted would be a direct reflection on the manufacturers of plates and films in that such a course would fail to recognize the elements of latitude and endurance in those products, which elements, as has been said, are of greater importance than speed in an emulsion for general use.

The author believes that should photography come to be practised on a more certain basis, dry plate and film manufacturers would find it simpler and therefore more advantageous to

reduce the number of brands which are made and endeavor to limit their several speeds to differences of at least one hundred per cent. In photographing a person of rather dark complexion the exposure should be about four times as great as that for a very fair complexion in the same light and green trees may easily require an exposure sixteen times as long as white clouds, both being in direct sunlight. With such varied conditions of subject always before us in nature there is in reality no advantage in having two brands of emulsion so near alike in speed as is now frequently found to be the case.

The definition of exact exposure has been much discussed. A perfect exposure, in the opinion of the author, is one which creates in an emulsion a latent range which may be developed under known conditions and without special attention, into exactly the character of negative which the worker in that particular case desired to obtain. Should it be desired to secure two distinctly different negatives of the same subject, one with but little detail in the shadows and another with full detail or extra softness the exposure for the latter might easily be sixteen times that for the former, as has already been explained, and if both plates develop without special attention into the desired characteristic negatives both the exposures may be considered correct. In other words and from a purely

practical view point, a perfect exposure is one which accomplishes the desired results. This is not at all inconsistent with Hurter and Driffield's definition of a technically perfect negative discussed in chapter VIII.

To make a correct exposure therefore one must have a foreknowledge of the photographic value of the light coming from the various parts of the subject to be photographed or the contrast of that subject and must know that the latitude of the emulsion in hand is suitable for the reproduction of such a contrast. Good taste and judgment should also have determined the characteristic quality of tone and gradation desired in the finished print. This gradation must be considered furthermore in its relation to the hardness or softness, i.e., the tone latitude, of the paper or other medium upon which the picture is to be printed. Ordinary care and attention to each step in the work is all that is required to reach the above standard of efficiency in exposure.

CHAPTER II

ACTINISM AND DIAPHRAGM SYSTEMS

A NEW PHYSICAL QUANTITY

WE are endowed by nature with what may be termed a sense of quantity values and it is this sense which is gratified by the use of measurements of all kinds.

In order to apply rudimentary knowledge to the practice of photography it is necessary to develop in the mind the idea of a value not before met with — that of *actinicity*. This is defined as the capability of radiation to produce certain chemical changes on converging at a point. This property is possessed by light from all surfaces about us ranging from that of the sun to that of some surfaces quite invisible. Until it is fully understood that each surface in nature and each subject as it comes before the lens has in its different planes actinicity to a measurable degree and that these values are expressible in simple numbers, the problems of photographic exposure cannot be intelligently solved.

It will be shown that the speed of a plate or film may be for example one minute (or 64

seconds which may be substituted for one minute as it is one of the terms in the geometric series of base 2 as used throughout this treatise; pp. 21, 26), and this time is simply the proper or normal exposure with that plate or film when there exists in the subject a one unit actinicity and the unit diaphragm is in the lens. Now if it be ascertained by measurement that the actinicity of a surface is 16 units, then it is evident that the required exposure will be only $\frac{1}{16}$ of that which would be required should the subject be of only one unit actinicity, or in the above supposed case, $\frac{1}{16}$ of 64 seconds or 4 seconds. Again, since this 4 second exposure is calculated on the basis of the unit diaphragm it is evident that should the 4 unit diaphragm be used the exposure would be only $\frac{1}{4}$ of 4 seconds or 1 second. That is to say, the speed of the emulsion divided by the actinicity of the subject gives the exposure with the one unit diaphragm and this exposure divided by the diaphragm used gives the exposure with that diaphragm.

This simple measurement, which is so easily and quickly made in any case, should end forever those unnecessary complications due to the hour of the day, the season of the year and the latitude in which one is working, as well as those due to temporary conditions of the weather and the color or *inherent actinicity* of the subject to be photographed (p. 59).

It is a simple enough idea to which we are

educated, to think of the temperature of a room as being 70° for example, and we do this without any special or technical knowledge of the science of heat. Also then without being highly educated in physical optics the reader is asked to recognize the special capacity of radiation to effect chemical changes as in photography and which is called actinism. Light from all sources is actinic to some degree, and we speak of the actinicity of a source, of the sky for example, as a measure of the quantity of effect produced under specified conditions by the light converging from this source. The appreciation of the reality of this property and the ability to measure it with certainty or with all the exactness required, go a long way toward establishing a firm scientific basis for the practice of photography.

THE ELEMENT OF TIME

This is one of the basic factors in the study of actinometry and in the practice of photography. As a child the writer believed the duration of a second to be inconceivably short and it is certain that children generally have a very abstract idea of its duration. A simple system for counting seconds accurately might profitably be taught in the kindergarten by the use of a clock which ticks seconds. In this way the pupil would learn to think time rythmically, something as one feels the rythm of music.

In the daily practice of photography it is of fundamental importance that one should be able to count time correctly and the following method should be practised diligently:

A quarter second. . . . ."quar – ter."
A half second . . . . . ."naught – one – half."
One second . . . . . ."naught – one – half – and – one."
Any number of seconds ."naught – one – half – and – one,
one – half – and – two,
one – half – and – three,"
etc.

In learning this method it may be practised by placing a coin or other convenient object over any suitable spot or mark and uncovering and covering that spot as the different intervals of time are counted. For example to count and expose the mark for a half second, slip the coin off exactly as the word "naught" is spoken and return it on saying the closing word "half." This will be illustrated by the following arrangements:

(off) (on) (off) (on)
"naught – one – half," "naught – one – half – and – one,"

(off) (on)
"naught – one – half – and – one, – one – half – and – two," etc.

The importance of perfecting this method cannot be overestimated. Workers may find diversion in competing with each other in counting the longer intervals of time, say from a half minute to a minute or more. One should be able to count a minute with not more than two or three seconds of error.

Photographic shutters which mark off automatically different intervals of time should be graduated to the following geometric intervals in seconds: 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, $\frac{1}{128}$, $\frac{1}{256}$, $\frac{1}{512}$, $\frac{1}{1024}$, etc., or so far as the rapidity of the shutter will permit. Shutters as now made are usually marked with the following time intervals: 1, $\frac{1}{2}$, $\frac{1}{5}$, $\frac{1}{25}$, $\frac{1}{50}$, and $\frac{1}{100}$. It frequently occurs however that the intervals marked 1 and $\frac{1}{2}$ second respectively result in practically the same exposure and that about a half second. The time marked $\frac{1}{25}$ on some shutters results in more than double that time. When the method of counting time above given is mastered, the errors of the longer intervals of such shutters as those of $\frac{1}{2}$ and 1 second, may easily be detected by the unaided ear.

Rather than use the automatic action of the shutter for the intervals of one half second and longer the index should be placed at "T," and such exposures made with two distinct pressures of the bulb. This is advisable as should the subject begin to move during an exposure the shutter may immediately be closed. Should the exposure be given with the automatic action this of course would be impossible. This premature closing of the shutter would result of course in some under-exposure but the negative might still be usable should the first movement of the subject not have been sufficient to blur the image. The quarter second exposure can

Plate II — MARGUERITA

best be given with the index at "B," and with a single pressure and release as in speaking the word "quar-ter," as instructed. The ideal shutter would begin the automatic exposures at $\frac{1}{4}$ second leaving the half and one second and all longer exposures to be given by hand. In this manner the unreliable valve and plunger mechanism of shutters could be discarded entirely as the quarter second and the shorter intervals no doubt could be given without it.

If in the solution of any problem in light the time interval be 512,000 seconds or greater, the number may be reduced to 8000 minutes or more, or if necessary to the equivalent time in hours, always considering however, 64 minutes as being freely interchangeable with one hour as 64 seconds are with one minute. The use of the geometric scale is thus preserved without measurably disturbing results in practice. Also the geometric interval of 1024 seconds or minutes and the greater intervals may be considered as even thousands and written 1M, 2M, etc. In reading these terms however the letter should not be pronounced but the word "thousand" instead, as, 1M for example is pronounced "one thousand," etc.

PLANE AND SOLID ANGLES

If two mutually perpendicular lines be drawn through the center of a circle, four right angles are formed, each subtended by *one* quarter of

the circumference. Again, each of these quadrants may be halved or further subdivided at will. If now three planes mutually perpendicular be passed through the center of a sphere, eight equal solid angles are formed called octants, each subtended by one eighth of the spherical surface. If further a circle be drawn on the surface of the sphere equal in area to one of the octants, this circle may be said to subtend a solid angle at the center equal to one eighth of the sphere, and the solid geometrical figure thus defined will evidently be a circular cone with its apex at the center and having a spherical curved base. From this it is seen at once that, if straight lines be drawn from any point in space to every point of the outline of some subject as a door or window, the latter will subtend at the point a definite measurable part of the total solid angle subtended by a spherical surface drawn about that point. Evidently as the point approaches the object the solid angle subtended will increase.

If the apex of the cone of light subtended by the door or window in the foregoing illustration be located upon some light sensitive surface, as that of a silver emulsion, then the greater the convergence of light from that source, the nearer the emulsion to the window or door, the less time will be required to produce a stated chemical change. Now as every object about us, even one so indefinite as the sky, emits light

capable of effecting this chemical change to some degree, this property is evidently a quantitative one and as will be shown can be measured in simple units. This property has already been termed actinicity.

In taking up the discussion of the unit of actinicity it must be understood that the purpose of this system is not to suggest a primary light source of unit power as a standard but to furnish a practical means of measuring and expressing in simple numbers the intrinsic actinicity of all light sources, as the sun, the sky, flames and all visible surfaces about us in nature.

THE F SYSTEM

It can easily be demonstrated that if a circle be drawn on the surface of any sphere equal in area to one half of one of its octants above referred to, the diameter of this circle will equal approximately the radius of the sphere and therefore the altitude of the corresponding cone. Now, as is well known, the usual method of denoting the light admitting property of a photographic lens, is to express the ratio of the diaphragm diameter to the focal length of the lens; hence the focal or *f* system.

Thus in the accompanying diagram if *ab cd* represent a bundle of parallel light rays incident upon a lens, *o*, the light will be concentrated at the point *e* called the focus and situated at the distance *oe* from the lens known as its focal

length. The focal length for a lens of any given diameter is evidently dependent upon the curvature, the refractive index of the glass, etc., but the amount of light per unit area of the spot at *e* is directly proportional to the area of the lens opening or to the square of *bd*, and inversely proportional to the square of the distance *oé*. The intensity of the effect at *e* therefore is proportional to the square of the ratio of *bd* to *oe*.

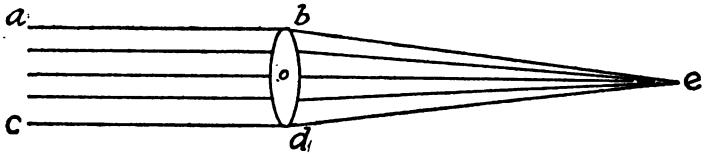

Figure 1

This ratio *bd/oe* is called the *relative aperture* of the lens and is the basis of the *f* system for indicating lens speeds. For example if a lens of 16 inches focal length is used with a diaphragm opening 2 inches in diameter, the former is eight times the latter and the relative aperture is expressed $f/8$ ($\frac{1}{8}$). If the full opening of this lens be 4 inches in diameter the focus is only four times this diameter and the relative aperture will therefore be $f/4$. As the base of the cone of light admitted with the $f/4$ opening is four times the area of the base of the $f/8$ opening, the altitude or focus being the same, the illumination at *e* will be four times as intense with the former as with the latter and the necessary exposure for taking a picture one fourth as great.

DERIVATION OF THE UNIT CONE

Referring now to the spherical cone in which the diameter of the base equals the altitude, it follows that it might be described as being equivalent to a relative aperture of $f/1$, and as every point of the surfaces about us in nature is a point of convergence of cones of light emitted from all the objects which confront it, it becomes necessary to evaluate these cones as a means of determining one of the elements of actinicity. A unit of measurement must then be sought and defined.

Since it is the custom to graduate lens diaphragm scales so that each number in the series indicates a speed half that of the next lower, the idea was suggested that by successively halving a spherical surface a small cone might be attained approximating in value one of the smallest practical values in the f system. This is evidently the case since an $f/1$ cone has been seen to be approximately $\frac{1}{16}$ of a sphere. Now since $f/64$ is the smallest practical relative aperture used in photography, it is at once suggested to adopt the corresponding cone as the unit cone. Since $f/1$ equals $\frac{1}{16}$ of a sphere, and the cone values diminish inversely to the squares of the f values, $f/64$ will equal $(\frac{1}{16} \times \frac{1}{64^2}) = \frac{1}{65536}$ of a sphere. As mathematical accuracy is not demanded this fraction may conveniently be abbreviated to $\frac{1}{64000}$ and may be written $\frac{1}{64M}$, as

has already been explained. By the adoption of this particular number the geometrical progression with ratio 2 is preserved which much facilitates mental calculations. Practically all calculations in this treatise are based on this geometrical progression which has already been employed in the chapter on time.

Since it has been shown that the unit cone system and the *f* system of designating lens

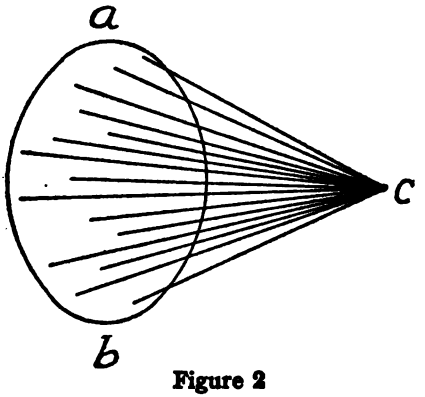

Figure 2

speeds are entirely consistent mutually, it is the present purpose to extend the latter as a basis for the calculation involved in many other problems in light. For example if a circular illuminated disk of any diameter, as *a b*, in the accompanying diagram, be thought of as sending light from each of its points to a point *c* whose distance from *a b* is equal to the diameter of the disk *a b* we may speak of the distance from *a b* to *c* as the focal length of the cone and in this case also the relative aperture or the solid angle

of the cone at *c* would be *f* / 1 just as if *a b* were a lens transmitting light. Just as in the case of a lens it is the *ratio* of *a b* to the distance of *c* which is important and upon which the working speed depends, and *not* the value of either alone. It is thus seen that the *f* system so long used in denoting lens speeds is equally applicable to the ordinary conditions of light in nature. It should be remembered however that the *f* system is only a *convenience in describing the form of cones,* and that comparisons and computation are possible only on the basis of the *solid angle* of the cones, which is their basic, or working-quantity value. Hence the need of the cone unit valuations on lens stops instead of the *f* and U. S. scales which confuse by not evaluating. In this case the cone value would be 4,096 or 4M units as will be seen from the table which shortly will follow.

THE U. S. OR UNIFORM SYSTEM

It will be necessary here to give an explanation of the Uniform System for numbering diaphragms for the reason that this method is the one now in use on the majority of double lenses in the United States, where, until recently, lens makers employed it in marking their lenses.

This system was originally recommended by the Royal Photographic Society of Great Britain which body later discarded it in favor of the *f* system which at the present time is quite generally used throughout the world.

The Uniform System numerically is just the reverse of a cone unit system since its numbers are proportional to the time of exposure required by each opening, beginning with 1 which is the equivalent of *f*/4, as will be seen in the table which follows. This system was a failure in that it was an attempt to do too much, i.e., to furnish a series of relative exposure numbers already worked out for each opening in the lens instead of giving to each opening a number, as does the unit system here recommended, indicative of its true working power or solid angle, leaving the operator free to exercise his reason in solving exposure problems as simple matters of cause and effect.

The author is convinced that less than ten per cent of those who use either the *f* or the uniform systems of diaphragm markings are aware of the derivation of the terms employed. Practically none use the scales in a purely mathematical sense but arrive at a certain proficiency through experience, having learned that each opening requires double the time of exposure that the next larger one does. This state of accuracy could be reached as well should the diaphragms be *lettered* instead of numbered and I have read that some authorities have been of the opinion that the letters would be much simpler in practice than numbers, since the relative working speed could be known and utilized as well and the numbers would cease to confuse

those who did not know their derivation nor comprehend their meaning.

THE UNIT DIAPHRAGM SCALE

This diaphragm scale is different from all others in that it is a geometrical series of cone values starting with that of $f/64$ as unity. These diaphragms therefore do a certain work in more or less time as there are a lesser or greater number of units working and exposure problems are in this manner brought under the ordinary processes of reasoning. It is strongly recommended therefore that this unit scale be substituted on all lenses and shutters as a preparatory step in learning the theory and practice of this system. In the scheme defining the unit cone (p. 25) the principle involved in the unit method of diaphragm numbering is fully explained.

In order to substitute the unit scale for that of the *f* or U. S. scale which is already applied to the lens, it is necessary only to substitute the equivalent unit scale numbers for those of the old scale. Find in the *f* or U. S. column (see table, p. 32) the numbers already on the lens and the equivalent unit number in each case will be seen on the right in the column headed "cone unit value."

On request makers of lenses ought to supply unit scale plates interchangeable with those already attached to their lenses. The worker

may easily make for himself however a thin, stiff card-board plate or even a metal one having the same form as the diaphragm plate on his lens or shutter and mark the intervals or lines on it in the same position as on the original plate but using the unit scale numbers. This plate should then be fastened in the position of the original one.

If preferred the diaphragms may be determined and the scale applied with practical accuracy by the following method. If the focal length of the lens be not known, find it with sufficient accuracy by measuring the distance from the diaphragm to the ground glass when distant objects are in focus. One sixteenth of this distance gives the diameter of the stop which is numbered 16 in all the scales as will be seen in the table on page 32. It subtends in double lenses of popular construction, 16 cone units at a point on the plate since it has 16 times the solid angle of $f/64$, the unit cone and diaphragm.

Now multiply this diameter by 1.41 ($\sqrt{2} = 1.41+$) which will give the diameter of the 32 unit diaphragm or number 32 of the unit scale. Then, doubling the diameter of diaphragm 16 gives consecutively the diameters of the unit scale numbers 64 and 256 and by halving it consecutively are obtained the diameters of diaphragms 4 and 1. Doubling the diameter of number 32 gives consecutively numbers 128 and 512 and halving it, the numbers 8 and

Plate III — HASTENING HOME

2. There remains only to place the index or lever so that the openings assume these respective diameters and mark the position of the index with the corresponding unit scale number which is simply the unit value of the cone formed when the index is in that position. In sizing the diaphragms as just described iris diaphragm shutters should be *snapped* open to get the size, instead of using the shutters open and approaching the size with the stop lever. This is advised in order to obviate errors due to any possible lost motion in the shutter mechanism. The author has observed cases in which at the small openings an error of more than 100 per cent would be made by disregarding this advice. Of course if there is excessive false play the shutter should be repaired or discarded.

Multiplying the diameter of one diaphragm by 1.41 to obtain that of the next larger or the one having double the rapidity of the first is in compliance with the fact that circles having areas varying as the numbers, 1, 2, 4, 8, etc., have diameters which vary as the square roots of these numbers or as 1, 1.41 +, 2, 2.82 +, etc.

With regard to the small hand cameras of the Brownie and Buster Brown type, the "large," "medium," and "small" stops may best be considered in the unit scale 32, 16, and 4 respectively. The single diaphragm in the still smaller or "one diaphragm" cameras may be considered as unit number 32.

The table which follows expresses the sphere value, the *f* number, the U. S. number and the cone unit value of all cones from *f*/64 to *f*/1:

Sphere value	*f* number	U. S. number	Cone unit value
1/64M	*f*/64	256	1
1/32M	*f*/45+	128	2
1/16M	*f*/32	64	4
1/8M	*f*/22+	32	8
1/4M	*f*/16	16	16
1/2M	*f*/11+	8	32
1/1M	*f*/ 8	4	64
1/512	*f*/ 5.6+	2	128
1/256	*f*/ 4	1	256
1/128	*f*/ 2.8+	1/2	512
1/64	*f*/ 2	1/4	1024 or 1M
1/32	*f*/ 1.4+	1/8	2048 or 2M
1/16	*f*/ 1	1/16	4096 or 4M

At the beginning of the preceding discussion it was stated that a cone equal to 1/16 of a sphere was only approximately *f*/1, and it follows of course that the equivalent values in the above table are only approximate. The approximation however in the case of that which we have chosen as the cone unit is very close. As a matter of fact 1/65,536 of a sphere (that given as, 1/64M in the first column), is equivalent to *f*/63.99 + instead of *f*/64. In the higher values the error is a much higher percentage of the whole quantity involved, but the allowable variation in photographic exposure time is so great as to make even these greater differences quite negligible in practice.

The author realizes the difficulties in the way

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of the general adoption of a new diaphragm scale, especially as many thousands of lenses and shutters are already in use graduated in one or another of the older systems. It must prove an attractive system indeed that will induce the photographic worker to rearrange the diaphragm scale of his lenses. Those who realize the advantages of a unit method in raising photography out of the chaotic state of its present practice, will do well to urge their respective societies to adopt this method unless a still more practical unit may be decided upon. Only in this manner will it be possible to interest the various National Bureaus of Standards and secure their aid in establishing an international unit and scale. (See beginning of Chapter IV, p. 49.)

CHAPTER III

UNIT ACTINOMETRY

THE F./1 ACTINOMETER

THIS may be any box arrangement as shown in profile in figure 3, having an opening the diameter of which (*b c*) is equal to the distance through to the opposite side of the box (*bb*¹). Such an opening with reference to the point *f* on the opposite side subtends 4M cone units in solid angle and is *f*/1 in form. There must be a small opening (*d*) opposite the larger one immediately behind which may be placed a small strip of tinting medium (*e e*) to receive the light as from the surface *a a*. This small opening is termed the "contact" opening. It has no optical significance and is always made of a size sufficient to enable a tinted spot made through it to be plainly seen and examined.

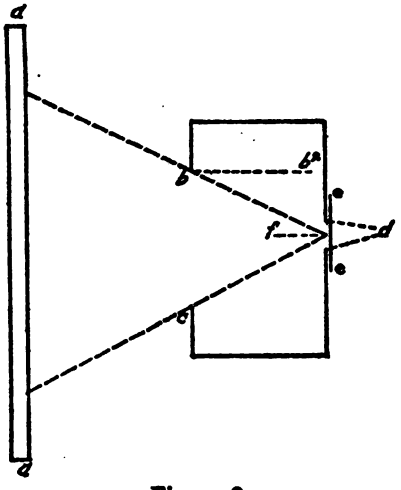


Figure 3

For practical use these conditions may be secured in the following manner. Procure a small pocket note-book with a tough, flexible paper cover and a small, shallow pasteboard box either square or circular and not over a half inch in depth, such as may be found in any drug store. Bend down the top corner of the front cover as indicated by the dotted line in figure 4 and press it down slightly so that it will hinge when lifted afterward. Cut a circular hole in the box cover making its diameter the same as the thickness of the box thus establishing the $f/1$ form of opening illustrated by figure 3. Now lay the cover of the box on the corner of the book rather close to the hinge and with a pencil mark on the book cover the position of the center of the opening. Cut at this position the contact opening described in the last paragraph. An irregular form is a help in observing the tinted spot to be made through it and the star shaped opening seen in figure 4 is made by first cutting a triangle and then notching each of its sides. As has been stated this should be only of a size sufficient to

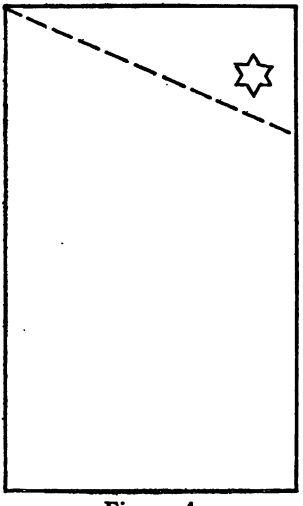


Figure 4

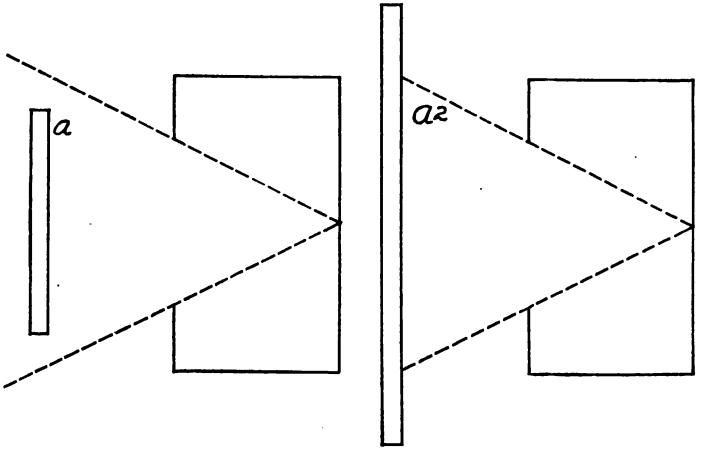
enable the spot tinted through it to be readily seen and examined, say approximately a quarter of an inch in diameter. Next cut a hole in the bottom of the box opposite the one in the lid and a little larger than the contact opening in the book cover when, after lining the box and cover with black velvet or painting it inside with some dull black medium and pasting or glueing the book cover, box and lid together so that all the openings will come opposite one another, the meter will resemble figure 5 and is ready for use.

It will be well also to make a contact opening in the back cover of the book, without a box attachment, for measuring the light *at* or incident upon surfaces as distinguished from that omitted *by* them. This distinction will presently be explained. Holding the book as though the back were the front, i.e., in an inverted position, cut the contact opening at the top as the book may then be handled with the same convenience as though the opening were at the top of the front cover. Bend over the cover to hinge it as previously explained. Figure 4 illustrates perfectly this contact opening. The first leaf of the note book may be faced with a strong, unruled, white paper which will aid in distinguishing the tints to be obtained on the tinting strips.

These consist of sensitive strips of convenient length, a little wider than the contact opening,

Figure 5

which may be cut from an ordinary roll of film or from one of the films from a film pack or better from some smooth, fast bromide (not gaslight) paper. (See p. 44.) Similar strips of some gelatine printing out paper also should be provided. Small pockets of black paper may be pasted in the book to hold these strips or they may be carried safely between the leaves.



Wrong Figure 6 Right

To use this $f/1$ meter two basic conditions must be observed. One is that the distance from the surface whose actinicity is to be measured to the surface of the tinting strip, through the meter, must be somewhat less than the width of the surface being measured. Or in other words the meter must be held, in practice, a little closer to the area measured than the least width of that area, as illustrated by the accompanying

figure. It is seen that the surface *a* does not fill the full angle of the cone of light which enters the meter and that surface *a*2 does so and hence complies with the conditions mentioned and which must be observed in using the meter. The other condition is that any area to be measured must be of quite *uniform intensity throughout.* Otherwise it is evident that a single intensity is not being measured but only an average measurement of different intensities.

ACTINIC MEASUREMENTS OF AND AT SURFACES

It is necessary to distinguish clearly measurements *of* and *at* surfaces. The measurement *of* a surface is directly made by the use of the *f* / 1 meter and may be made in any case in which the light impinges from a uniformly intense surface. This is a direct measurement of the *intrinsic actinicity* of a surface. The measurement made *at* a surface is made by holding the book with the contact opening (not the *f* / 1 meter) *at* or near the surface and by taking the activity of the light impinging upon that surface from the confronting sources. In this case the light source may be of an irregular nature as no attempt is being made to measure it but only the intensity which is created by all the light sources which confront the contact opening throughout the whole hemisphere of space.

In using the contact opening, some object, as a coin, should be held over it while the tinting

strip is being placed in position and the strip should be shielded carefully from strong light at all times except of course when the measurement is actually being made. This precaution is almost as important with the slow tinting medium as with the film although the latter tints with great rapidity in strong light and must be well shielded on examining the tint as well as when placing it in position. In using the contact opening the coin instead of the thumb, avoids perspiration marks on the tinting strip and also allows a freer movement of the hand and arm in making the shorter exposure of a half and quarter second.

THE LEAST VISIBLE TINT AND THE FIRST APPEARANCE TIME

The least visible tint is the faintest spot which it is possible to distinguish on any tinting medium on exposing it to light behind an opaque screen in which a hole has been cut (p. 35). The tint is observed by raising the hinged corner of the cover away from the tinting strip when, if the exposure has been just right, the form of the opening will be *just* visible in contrast with the original white or light color of the same medium where it was protected from the light.

The advantage of the least visible tint as a standard is that no device is necessary on which to carry another tint for matching, as the comparison is made, as has been said, between the

Plate IV— HILLSIDE FLOWERS

Microfilm

tint and the untinted part of the same medium. Also the method of comparing different tinting mediums which will be given (pp. 47, 156) enables any desired medium to be used in connection with its own tinting speed factor referred to a chosen medium as a standard.

The time required under any circumstances to obtain the least visible tint is termed the *first appearance time*, or in practice simply the "tint time" of the light. If it be the time as taken with the standard or $f/1$ meter it may be spoken of as the meter time.

Every photographic worker should understand perfectly how to secure the least visible tint. A feeling of doubt generally assails one on first attempting to obtain it, but a little practice under various conditions of light will overcome this feeling entirely.

One should become familiar with what may be termed the *disappearing scale* of tints which will now be explained. For experimenting use strips of gelatine p.o.p. such as "solio" already mentioned. Having placed one of these strips behind the contact opening in the back of the book, first having covered the opening with a coin as has been directed, make a series of exposures under the same conditions except that each is half as long as the preceding. Stand a few feet back from a window and start with an exposure of 32 seconds, having the book face the window. The strip should be shifted

to a fresh place for each successive tinting. On examining the series of tinted spots the first will no doubt show considerable discoloration while the depth of tint decreases with a characteristic gradation which will at once be recognized. If the experiment be successfully performed there will be one exposure which results in a tint only just distinguishable from the untinted part of the paper. This is what has been termed the least visible tint and the one intended by the author to be the tint sought for in the measurement of light by the present system. The time required to make this tint is the first

Figure 7

appearance time or the tint time of the light as already explained. The accompanying figure illustrates the characteristic gradation of the disappearing scale of tints.

After a few experiments in making this disappearing scale one becomes so familiar with the gradation steps as to be able to estimate at a glance, on securing any tint, its approximation in the scale so that a single other trial will usually result in the desired least visible tint.

THE ABSOLUTE ACTINIC UNIT. THE ACTINO

Logically the absolute unit of actinicity must be defined as the rate of emission of radiant

energy from a surface just actinic enough to produce the least visible tint on some conventional standard medium in one second when the convergence is one cone unit. As in the case of many other absolute physical units this is impracticable in ordinary use since measured in this manner the surface of the sun itself when high in the heavens and the atmosphere clear, would have an actinicity of only 128 units and all ordinary intensities would have to be expressed in fractions. A surface as bright as the brightest sky would have only about 1/512 of this unit actinicity. It is evident therefore that a much lower actinicity must be chosen as the practical unit. The unit actually chosen is that rate of emission which will produce a least visible tint in one minute (or 64 seconds) when the convergence is $f/1$ (or 4M cone units). This practical unit of actinicity is called an *actino*. Using the ordinary emulsions as the standard tinting medium, this practical unit gives the brightest sky an actinicity of about 512 actinos and the sun about 32,000,000 actinos. The practical reason for choosing this intensity as the unit is that ordinary surfaces about us, as for example a face when lighted as for making portraits, will have an actinicity of from 8 to 64 units. It is seen therefore that the value of the practical unit of actinicity is chosen purely for convenience in practice just as the practical units in other departments of physics have been chosen.

THE STANDARD TINTING MEDIUM

Many speeds of dry plates and films are made, i.e., many degrees of latent sensitiveness, but the author has found that the rate with which these emulsions visibly discolor on exposure to light is practically the same in all and for this reason all ordinary dry plate and film emulsions may be considered as standards for measuring actinism until an international standard shall be adopted. On account of the greater ease in working, the tinting strips will be cut for the most part from the small sizes of roll film, which fact will practically limit the standard to some half dozen different factories in the United States and in Europe. Avoid for this purpose films having any orthochromatic dye as they are thus rendered slower as to their tinting speed. A smooth bromide paper of sufficient tinting speed would be the ideal medium to use and some suitable paper might be taken as a standard. Although a standard of this character is not entirely satisfactory to the author no inaccuracy can result in practice since each worker, should he follow out this method fully, will ascertain the speed of the plates or films which he uses, on the basis of the tinting medium which he may find convenient. Thus the method is found to present a very desirable elasticity in practice.

It is hoped that by the united efforts of the many photographic societies both here and

abroad some specific tinting medium may be generally adopted as a standard. The flexibility of this method is such that no difficulty whatever would be experienced in adopting a standard at any time.

Surfaces, which word will hereafter be used through lack of a more general one to express all light sources, as flames, surfaces and masses, such as the sky, clouds, etc., may be compared as to their actinicity by allowing the light from them to do a certain fixed amount of work through the standard opening of the actinometer having a convergence of 4M cone units and the form of $f/1$. As has already been explained, this fixed work shall be to discolor the standard tinting medium to the standard or *least visible tint.*

As a practical example, the walls of the room in which the writer is now working are in moderate light and on adjusting a strip of standard film in the actinometer which has been described, and exposing the meter for 64 seconds to a uniformly lighted part of the wall through the $f/1$ opening, it is found that a decidedly deep tint was secured. On moving the strip along to a fresh place and exposing for 8 seconds no tint was visible but 8 seconds more given to the same spot, making 16 seconds in all, produced the least visible tint. Now since an intensity which will produce this tint in 64 seconds has been selected as the unit, this wall must

be 4 units in intensity since it created the tint in 16 seconds or in one quarter of the time required for the unit intensity to do it. The rule for finding the actinicity of any surface which is possible to measure with the standard meter is therefore as follows:

Rule: Divide 64, the number of seconds of first appearance time indicating one actino of intensity, by the first appearance time of the surface as measured with the meter and the standard tinting medium; the quotient will be the intensity of the surface measured in actinos.

As another practical example the intensity of the sky may now be found in actinos. Being much more actinic than the wall previously measured it will of course produce the tint in much less time, so it is first tested with a very short exposure, say of one second. Should the least visible tint be obtained by this exposure then the intensity of the sky would be found to be 64 actinos. But on examining the tint produced it is seen to be excessively dark and one second is therefore known to be much greater than the first appearance time. It is necessary then to give a shorter exposure than one second. On giving a quarter second exposure the tint is still seen to be rather dark, in fact it seems to resemble the second or third visible tint in the disappearing scale already described (p. 41). Now since one cannot make the next shorter or one eighth second exposure with the un-

aided hand it is found expedient to reduce the size of the opening by covering half of it with a straight edged black paper thus reducing its convergence from 4M to 2M cone units. When now another exposure of a quarter second is given, there results the least visible tint. This exposure is of course equivalent to one of 1/8 second with the full opening of 4M units. According to the rule, 64 divided by 1/8 gives the actinicity of the sky as 512 actinos.

TINTING MEDIUMS OTHER THAN THE STANDARD

It has been seen that in order to measure the actinicity of the sky with the standard film emulsion in the standard meter the time required to get the standard tint is inconveniently short. It is also true that the great sensitiveness and the consequent short time required to tint the standard film in strong exterior light makes the examination and detection of the least visible tint difficult. It is evident therefore that under such conditions an advantage would be gained if some slower tinting medium were used in the meter. In order to obtain the standard first appearance time from the use of any other slower or faster medium it is only necessary to know the relative tinting speeds of the two mediums and this may be known by simply comparing the speeds of those mediums with each other. For example under certain conditions the standard emulsion reveals a time

of 1 second while on placing a strip of gelatine printing out paper (p.o.p.) in the meter 8 seconds are required to get the tint. These are the papers of the class represented by "citrate," "disco," "solio," "sunrae," etc., and they will all be found of practically the same tinting speed. Considering then the standard emulsion as having a tinting factor of one, p.o.p. will have a factor 8 and on any occasion by measuring the light with the slower medium, the time found, divided by 8, will give the standard time sought. (See also pp. 41, 156.)

Thus in the case of the sky measurement previously made in which it was necessary to halve the meter opening, on using a strip of the slower tinting medium in the meter the time would have been found to be 1 second and this time divided by 8, the factor of the slow paper, would give the standard time of 1/8 seconds, the same as when measured with the standard emulsion.

It results also that with this slower medium a first appearance time of 512 seconds or 8 minutes indicates a one actino intensity just as 64 seconds or 1 minute indicates that intensity with the standard tinting medium and consequently that a one second time with the slower medium indicates a 512 actino intensity in the surface measured. This latter is proved by the sky measurement just made.

Plate V—VIEW FROM THE HAY LOT

THE SPECIAL NEED OF UNIT DIAPHRAGM NUMBERS

On seeing the *f* as well as the unit system employed in the problems in the following chapter, some reader may justly ask why the author should find the former so unfit for the numbering of lens stops. This has been explained but should be discussed more fully.

Suppose a simple exposure problem: If, under certain conditions, stop *f*/16 is found to require an exposure of 4 seconds what exposure will stop *f*/8 require? The rule with the *f* system is that the exposures vary as the squares of the *f* numbers and therefore the following proportion: 16^2 is to 8^2 as 4 is to 1, gives the exposure with *f*/8 as 1 second.

The trouble with this rule is that it does not disclose the *reason* for the answer which it secures. The nature of the computation requires for its *intelligent* working, a knowledge of the relation of cone values as involved in the *f* system and a knowledge of the geometric truths which concern the relation of the circumference of a circle to its diameter, including the extraction of the square root of numbers.

A small boy with a pile of wood to deposit in the wood-house is well aware that if he can get another boy to help him they can do it together in *half the time.* Just so one would analyze immediately the truth involved in stops if they were marked with their *values* only and could

be thought of the same as "one boy" and "two boys" at work. The truth is that with the *f* or any markings other than of simple solid angle *values*, the above rather advanced mathematical problems must be comprehended in order to perform a computation which *does not disclose at any step the basic principles involved.*

Why is the exposure with *f*/8 1 second when it is 4 seconds with *f*/16? In the analysis of this problem of simple cause and effect the "exact science" of mathematics admits of but one line of reasoning: "Stop *f*/8 requires *one quarter* the exposure of stop *f*/16 because it has *four times* the working dimension or solid angle of *f*/16. There *is* no other way of reasoning to be found for the problem and although the *f* or the U. S. numbers may be employed, or even though we might distinguish the stops from each other with the names of great mathematicians or of mythological gods, when we *analyze* the problem, we must come down to the same simple reasoning as that used by the boy with the wood to carry.

With stop numbers then, we *may* evaluate solid angle in simple units, and use them in computing exposure as we use the "dollar," "meter" and "grain" in computing problems of value, length and weight, or we *may not* do so and *whether we do so or not* is the one important matter in stop numbering.

The problem of the wood, calculated so easily

by the small boy, *can not be simplified* and that of calculating exposures with the help of solid angle unit values is exactly the same in character. By fixing this unit the requirements of science would be complied with, in that "the unit would be of the same character as the thing measured." Also it would be to the advantage of all who practise photography, even though they be children or people of little or no education, since only the simplest reasoning is involved.

Since a unit of actinicity can not be fixed without first fixing that of solid angle it may be truly said that the whole train of lamentable conditions in photography relative to exposure are due to the failure to recognize this solid angle dimension as a simple quantity value and fix a unit of it for use both in and out of lenses.

It will be well to group here the most important of these conditions:

Probably three quarters of the cameras in the world have been made and are still being made without stop numbers. If the use of stops were understood generally the public would demand that all lens stops be numbered.

The people who use these cameras as a rule simply *guess* at exposures and finally learn, through their failures, to confine their "shooting" to sunlighted subjects.

Next in number comes the professional photographer who as a rule judges the exposure by the appearance of the image on the ground-glass.

But the class of photographers which proves most directly the absolute weakness of present day methods are those who endeavor by all means to secure correct exposures and yet, finding no help which is based on simple "cause and effect" reasoning, are compelled to depend on purely arbitrary exposure methods which are designed to "get the answer" by means of a "sliding scale." Still more to be lamented is the fact that the present methods have kept the whole matter of light measurement and exposure so effectively separated from simple mathematics that these earnest people have quite concluded that there is no simpler way.

Then there is annually the immense money loss to the public due to exposures that are so wrongly guessed as to result total failures. In great part this loss is sustained by people who have been convinced by commercial advertising that photography was so simple that they could not fail.

Then there is to be added the injury sustained by the pride, the taste and the affections through the failures which are met with when certain greatly desired pictures fail to materialize.

In working out the following problems then, the *f* system is employed for conditions in nature *outside* of the use of lenses, and solely on account of its usefulness in arriving at the *form* of the light cone which converges from flames,

openings and expanses and from which form the solid angle of the cone may be easily computed mentally. That I have used the *f* numbers also in certain of the computations is due to the fact that, unlike the general practice of photography, only the illuminating engineer, the scientific photographer, the physicist and educator will be interested and such will comprehend the basic principles which underlie the solutions by the rules which are given for the *f* numbers.

The author desires not to be misunderstood regarding his opinion of the *f* system of numbers. The importance of this system is shown in the chapter on that subject and it would be extremely difficult to get along without its use in handling light problems of all kinds. His objection is to its irrational employment for numbering stops which need no numbers except the simple statement of their working dimensions in terms of a chosen unit.

CHAPTER IV

PROBLEMS IN UNIT ACTINOMETRY

PROBLEM 1: *To Find the Actinicity of Any Surface of Known Average Diameter and Known Distance from the Tinting Medium, i.e., of Known Cone Value.*

To illustrate this problem suppose that the average actinicity of a common kerosene flame is desired. Measure or estimate the average diameter of the flame and take its time at a distance of (say) two of its diameters from it. Its impinging cone is therefore $f/2$ in form. The time on the standard emulsion in the present case is found to be 8 seconds. Dividing this number by 4, the square of the f value gives a result 2, the seconds of first appearance time as though measured at $f/1$ or with the meter. Now, 64 divided by this time gives 32, the average intensity of the flame in actinos.

Rule: Divide the standard emulsion first appearance time of the surface at whatever f value measured, by the square of that f value. The quotient will be the standard meter time at the convergence of $f/1$ or as though measured with the standard meter. Its actinicity is now found in actinos according to the rule for using

the standard meter, i.e., by dividing 64 by the meter time.

In the case of a flame its *average* actinicity would be found by the above method, and this is what must be known provided it is to be used as a source of illumination for some other surface which it is intended to photograph. Should one wish to know the actinicity of the brightest part of the flame or that part a little above the center, then the base of the impinging cone to be measured must necessarily be confined to that part. This might be accomplished by placing a piece of thin metal with an opening in it a little smaller than the uniformly intense part of the flame, in such a position that the opening will come opposite and in close proximity to the flame. The measurement could then be made as before but on the basis of the diameter of this opening instead of that of the average diameter of the whole flame.

Although the preceding method is simplest in practice it is necessary to give another method based on the use of the cone units. The time was taken in the foregoing example at the convergence of $f/2$ and this cone is equal to 1M cone units. Then if 1M cone units will produce a least visible tint in 8 seconds one cone unit of that light source would require 1M times 8 seconds or 8M seconds. Now the standard time of unit intensity with $f/1$ is 64 seconds and with the one unit cone, which is only 1/4M of

f/1, it must be 4M times 64 seconds or 256M seconds. Then since the one cone unit time of the flame is 8M seconds the flame must be as many actinos in intensity as 8M is contained times in 256M which is 32 times. Therefore the intensity of the flame is found to be 32 actinos as before.

As another illustration, to measure the actinicity of the sun it is necessary as in any other case to confine its cone to a convenient *f* value and as the sun's total *f* value in relation to any point on the earth's surface is approximately *f*/108 it is best to reduce it to the form of *f*/128 to preserve the geometric series by 2. This may be accomplished simply by arranging to let it shine through any small opening while the tinting medium rests at 128 times the diameter of that opening distant from it. Let down the top sash of a window through which the sun is shining, sufficiently to allow the sun's rays to enter above it without passing through the glass and then cover all but one top corner of the window with a dark cloth. At this corner arrange a black paper, large enough fully to cover the opening, in such a position that a circular opening a half inch or 1 cm. in diameter will be at right angles to the sun's rays. Then on a slow tinting medium, say solio paper, take the first appearance time of the sun's light 64 inches or 128 cm. from the opening. This has been found by the author to be 1/2 second when the

sun is at about 30° from the horizon and the atmosphere clear. Now this time is divided by 8, the tinting factor of solio to find the standard tint time, which is 1/16 of a second. Now proceeding by the first rule given, the tint time as found with the standard medium, 1/16 of a second, is divided by 16M, the square of 128, the *f* value of the cone employed, giving $\frac{1}{256M}$ of a second, the time as though measured at *f*/1 or with the meter. Then 64 divided by this time gives 16,000,000 (or 16MM), the intensity of the sun's surface in actinos. The reader should work this problem also by the unit cone method which is more truly a method of analysis. At the zenith the sun would show double this actinicity or 32 million actinos as already stated.

It may be well here to call attention to a truth of nature which concerns the study of it by this method and that is that the expression "the actinicity of a surface" always implies the actinicity as effective at the point of the impinging cone where a measurement is taken. Just as we see objects in nature through a layer of air, smoke or mist, so also the lens must photograph them. It is in this sense that the sun may be said to have an actinicity of 32MM actinos at the zenith, one half of that at 30° from the horizon and, as the author has found under clear weather conditions only 64 actinos when its lower rim rests on the horizon.

Problem 2: *To Find the Actinicity of a*

Distant Surface of Small Convergence and Low Value. The moon is a good example under this problem. The actinicity of such surfaces may be found by securing the least visible tint in the position of the image of such a surface, that image being formed by a lens working at a known convergence. The *f* value of the lens as it casts the image is taken as the basis of calculation instead of the *f* value obtained as in the problems of the sun and of the kerosene flame.

For example, on a clear night when the moon is 30° from the horizon its image is cast by a lens working at *f*/4 and on taking the time with the standard film in the position of that image it is found to be 32 seconds. The problem from now on is exactly as the previous one of the kerosene flame. This time 32 seconds divided by 16 (4^2) equals 2, the time in seconds at *f*/1 and 64 divided by this number gives the actinicity of the moon's surface at that altitude as 32 actinos.

The use of the lens is simply to increase optically the cone value of the rays impinging from the source measured and thus to reduce the tint time to a more practicable length for measurement. The opacity of the glass in the lens retards to a measurable degree the strength of the light, but probably not over 20 per cent which is a negligible amount of it and the result, with this exception, is the same with the *f*/4 lens as though it were possible to approach

the moon itself to a point four times its diameter from it.

Problem 3: *To Find the Actinicity of Any Surface by Taking the First Appearance Time at That Surface or, in Other Words, of the Light Incident Upon it.* On measuring the light emitted from any surface, as already explained, the standard $f/1$ meter is used and should 64 seconds be required under any conditions to create the standard or least visible tint on the standard medium, it is known that the surface has an intensity of one actino. Should this tint be secured in 1/64 of that time or in 1 second, then it would be known that the actinicity of the surface equals 64 divided by 1, or 64 actinos. This standard method should be well understood by the reader by this time and is repeated here only for purposes of comparison. In obtaining the actinicity of a surface by the measurement of the light incident upon it, allowance must be made for the difference in what may be termed the *inherent actinicity* of surfaces by reason of their different colors or shades. This is that inherent quality that makes blue more intense than green and white more actinic than gray when in equal light conditions.

Suppose for example that a white, a blue, a yellow and a black cloth be arranged in the same light and that their respective actinicities be measured with the standard meter. The white cloth will be found to be the most actinic

and each of the others to measure less than the white in the order named. Should however the light *at* these surfaces or incident upon them be measured instead of that emitted from them, it is evident that the color of the surfaces could have no effect on the measurement, since exactly the same light falls upon each surface and the tinting medium would be turned directly toward that light instead of toward the surfaces.

Considering therefore the incident light, it is evident that one which would suffice to bring a white surface to a one actino intensity would not create so great an intensity in black, since it may be shown that ordinary black, as of cloth texture, has only approximately 1/16 the actinicity of white in the same light. This being true a black cloth would require to be illuminated with 16 times as strong an incident light as the white one in order to create the same actinicity.

To find therefore the actinicity of any particular surface by measuring the light incident upon it, it is necessary only to find what would be the first appearance time of incident light of such intensity as to bring the surface to one actino.

This time divided by the first appearance time *at* the surface as actually measured in any given case will give the actinicity of that surface in actinos.

This one actino time as referred to above

will now be found for different surfaces and given in a table. In working out this table the slower, or factor 8, tinting mediums are used and are recommended to be used in general practice for measuring incident light, since as already explained, the standard medium is too sensitive to be observed with ease under such intense light conditions. Should the light be so weak however as to make it advisable to gain time in taking the measurement, as after sunset or in dark interiors, the standard medium may of course be used and its time multiplied by 8, to reduce it to the equivalent p.o.p. time, which is used as the basis of calculation in this problem.

As the four surfaces mentioned above are arranged in the same light, as explained, a standard measurement *of* the white surface, with the standard tinting medium and the *f*/1 meter, results in a time of one second and its actinicity is found therefore to be 64 actinos, since 64 divided by 1 equals 64. Now on measuring the incident light with the slower tinting medium as recommended in this problem, the time is found to be 2 seconds. A 2 second incident light time with the slow tinting medium indicates therefore a 64 actino intensity for a white surface and from this it is evident that had the incident light been twice as strong the incident light would have measured 1 second instead of 2 and the intensity of the white surface would have been 128 instead of 64

actinos. Also it is clear that if a one second incident-light first appearance time with a factor 8 tinting medium indicates 128 actinos of intensity for a white surface, a 128 second incident light time would indicate an intensity of 1 actino. The one actino, incident light first appearance time with a factor 8 tinting medium is found therefore to be 128 seconds for a white surface.

To illustrate suppose that under certain conditions the first appearance time of the light incident upon a white surface, as measured with solio paper, is 8 seconds: Now it has been found and is a fact that a first appearance time of 128 seconds on such a tinting medium indicated an intensity of one actino in a white surface; therefore a first appearance time of 8 seconds indicates an intensity of 16 actinos $\left(\frac{128}{8} = 16\right)$. That is, a white cloth illuminated with such a light would measure 16 actinos.

Measuring now the blue cloth with the standard meter and medium its actinicity is found to be 32 instead of 64 actinos as for the white cloth. It is evident therefore that twice as strong an incident light would be required to bring it to any certain intensity, say to a one actino intensity, as would be required for the white cloth. From this it is seen that a 64 second first appearance, incident light, as measured with the factor 8 medium, is required to secure a one actino intensity for a blue surface

instead of 128 seconds as required for the white surface. As yellow is about one half the actinicity of blue in the same light it is clear that the incident light must be double the intensity of that for blue, or 32 seconds.

Suppose furthermore that with p.o.p. held near a yellow cloth the incident light time is found to be 4 seconds. Now since it has been found that a 32 second incident light is required to bring a yellow surface to an intensity of 1 actino, a light 8 times stronger, or one of 4 seconds time will evidently create an intensity of 8 actinos for that surface. Again, since a one second incident time indicated a 32 actino intensity for yellow, a 4 second time will indicate 1/4 that intensity or an intensity of 8 actinos. In like manner the intensity of a white cloth in that same light, is found to be 32 actinos.

To simplify this matter still further for the reader and at the risk of repeating, it may be said that under any condition, as for example in the shade of a house, should the incident light measure 1 second with one of the factor 8 mediums a white cloth would therefore be known to have 128 actinos, a blue one 64, a yellow one 32 and a red or a black one but 8 actinos. It is interesting to note in this connection that since the maximum incident light from the high sun and sky never passes 1/8 second on a slow medium the maximum actinicity of these surfaces by daylight can only be

eight times as great as that mentioned for a 1 second time, or for white 1M, for blue 512, for yellow 256 and for black 64 actinos.

Here follows the table of incident light, one actino, first appearance times for various colored surfaces, as measured with any factor 8 tinting medium, as citrate, disco, solio, sunrae, etc.

	Incident light time indicating one actino of actinicity	Relative actinicities in same light. Or actinic factors with white as factor one
White	128 seconds	1
Blue	64 "	1/2
Green	32 "	1/4
Yellow	32 "	1/4
Red	8 "	1/16
Black	8 "	1/16

As has already been explained the above numbers may also be considered as the actinicities of these different colored surfaces when their incident light measures 1 second with a slow medium. The actinic factors or relative actinicities in the same light are given as it may be necessary to refer to them later.

It must not be lost sight of that the effective actinicity as well as the luminosity of any surface is greatly influenced by the direction from which it is photographed or seen. This follows in accordance with well known laws of reflection. In the analysis of subjects practically, as will be explained later, these differences are allowed for in such a way as to make it unnecessary

further to consider them, except in certain special lightings in portraiture, as for example in the so called "line" lighting. In this and similar cases the narrow edge or "line" of light is greatly increased in intensity by the angle from which the face is photographed. Here however the incident light is measured when the window is arranged as for an ordinary front view lighting, and, while preserving this intensity as the basis of exposure, about half of the incident light is screened away from the face with some opaque screen, being careful that this screen be placed far enough from the window not to interfere with the light on the reflector which is used for raising the actinicity on the shady side of the face.

To further illustrate, suppose it is desired to photograph some red roses, and the first appearance time of the light incident upon them (always in the case of incident light it should be understood that a factor 8 tinting medium is used, unless otherwise stated) is found to be 4 seconds; what is their actinicity, and what will be the normal exposure in photographing them with a 4 unit diaphragm and using a plate having a speed of 128 seconds or 2 minutes?

It will be noted from the accompanying table that in an 8 second incident light, a red surface has an actinicity of one actino. Now since the incident light is twice as strong as this, measuring 4 instead of 8 seconds the actinicity

of the roses will of course be 2 actinos. Or, by the contrary method, the table shows that for red a 1 second time indicates an intensity of 8 actinos, and a time of 4 seconds, being only $\frac{1}{4}$ as strong, indicates only $\frac{1}{4}$ of 8, or 2 actinos as before. Now it has already been explained (p. 17) that the speed of a plate is the exposure time with diaphragm number one, unit scale, when the actinicity of the surface photographed is one actino. The surface being 2 actinos in intensity it will require, with the same, or unit diaphragm, one half of the plate speed exposure, 128 seconds, which is 64 seconds. Since, however, the 4 unit diaphragm is employed instead of the unit cone, the exposure is $\frac{1}{4}$ of 64 or 16 seconds. Or, if the 64 unit diaphragm be used the exposure will be 1 second, etc.

Again, a newly painted white building is in bright sunlight when the sun is high and the day clear; what is its actinicity?

In the paragraph dealing with bright sunlight conditions (p. 151) it will be seen that when the sun is high the first appearance time in the open with p.o.p. is $\frac{1}{8}$ of a second and that the light value is never greater than is indicated by this time. It will be remembered from the table that a one second time indicates for white an actinicity of 128 actinos and since a time of $\frac{1}{8}$ second indicates eight times as strong a light the actinicity of the building will be 8 times 128, which is 1,024 or 1M actinos.

Plate VI — 3300 HIGHLAND AVENUE

Rule: Divide the actinicity indicated by a one second first appearance time for any colored surface by the time as measured; the quotient will be the intensity of that surface in actinos. Or, divide the characteristic one actino, incident light, first appearance time for any surface by the first appearance time as measured; the quotient will be the actinicity of that surface in actinos.

Problem 4. *To Find the Actinicity of Any Surface when Illuminated by a Light Source of Known Actinicity and Convergence.* On a cloudless day lower the top sash of a window fronting the sky and close the lower part of the window with a black cloth so as to make a practically square opening in the top half. Arrange a white cloth vertically four widths of the opening distant from it and about level with its lower edge. The low position of the cloth practically compensates for the square form of the opening which of course admits more light than would a circular opening of a diameter equal to the width of the window. The slight error involved is of no practical consequence. The opening thus subtends with practical exactness an $f/4$ aperture at each point of the cloth and the convergence is therefore 256 cone units. Now disregarding both the cloth and the opening and making a standard measurement of the sky with the meter its intensity is found to be 512 actinos. A meter measurement of the cloth under the

conditions explained shows its actinicity to be 8 actinos. Now had the window subtended only one cone unit at the cloth instead of 256, it is evident that the actinicity of the white cloth would have been only $\frac{1}{256}$ of 8 actinos or $\frac{1}{32}$ of an actino. Furthermore had the intensity of the sky been only one actino instead of 512, then that of the cloth would have been only $\frac{1}{512}$ of $\frac{1}{32}$ of an actino or $\frac{1}{16M}$ of an actino.

It is found therefore that a unit light source, i.e., one of unit actinicity and unit cone value, will create on a white surface $\frac{1}{16M}$ of an actino of intensity. It is also evident that the intensity of a surface of a different color will be less than that of a white surface in the same ratio as the actinic factors of the two surfaces (p. 64). For this problem therefore is found the following rule.

Rule: To find the actinicity of a surface when illuminated by a light source of known actinicity and cone value; multiply $\frac{1}{16M}$ of an actino by the actinicity and again by the cone value of the light source; the product will be the actinicity of a white surface in actinos. To find the actinicity of a surface of another color multiply the actinicity of white by the actinic factor of that particular color.

Another method is as follows. It has already been ascertained (p. 48) that when measuring a maximum sky with a factor 8 medium in the $f/1$ meter, the time is 1 second and its actinic-

ity is 512 actinos. It is also known that a one second incident light indicates 128 actinos for a white cloth. Therefore it is seen that when a white surface is illuminated by any other uniformly intense surface at a convergence of $f/1$, the former has $\frac{1}{4}$ the intensity of that of the illuminating surface and also that a less convergence in the light source will cause a corresponding decrease of actinicity in the surface lighted. The second rule for this problem is therefore as follows.

Rule: Divide one fourth of the actinicity of the light source by the square of its f value; the quotient will be the actinicity of white surface in that light. As given in the first rule, this number multiplied by the actinic factor of any particular color gives the actinicity of a surface of that color.

If the sky, at 512 actinos, illuminates a white cloth through an opening $f/4$ in convergence, an actinicity equal to $\frac{1}{64}$ that of the sky or of 8 actinos, is created on the cloth. The whole hemisphere of sky whose convergence is approximately 128 times that of an $f/4$ cone raises the actinicity of the surface mentioned to only 32 times 8 or to 256 actinos giving it one half the actinicity of the sky itself.

This apparent falling off, judged from the point of view of the law of inverse squares, so rightly and frequently employed for small cones of light, is due to the fact that when a light

source approaches the solid angle dimension of a hemisphere in relation to a point which it illuminates, much of its light strikes the surface at a sharp angle and from a whole circle of directions and is again reflected off in such a manner as to make it impossible to measure the whole effect on any tinting medium.

In dealing with degrees of convergence much less than a complete hemisphere, as with $f/1$ and even $f/2$ cones of light, still another element of error enters. On doubling such relatively large openings *in a plane* the equal area added is farther from the point of impingement than was the former opening. This applies only when a small area opposite the center of the opening is being illuminated as in the $f/1$ meter.

It is for the sake of symmetry and clearness that the law of inverse squares is considered accurate for the calculation of light problems up to and including cones of $f/1$ convergence.

To illustrate this problem suppose a blue cloth to be illuminated by the sun at 30° from the horizon, through a hole $\frac{1}{8}$ of an inch in diameter and 32 inches distant from the cloth; what is the actinicity of the illuminated spot.

In this example the opening, being of less convergence than the sun itself, determines the form of the cone of light, which is seen to be $f/256$ $(32 \div \frac{1}{8})$. Since the unit cone is $f/64$ $f/256$ is equal to $\frac{1}{16}$ of a cone unit. It has

already been found that the actinicity of the sun at 30° is 16,000,000 or 16MM actinos. Now according to the first rule $\frac{1}{16M} \times \frac{1}{16} \times 16MM = 64$ and $64 \times \frac{1}{2}$, the factor for blue gives 32, the intensity of the spot in actinos. Or according to the second rule; $\frac{16MM}{4} \div 256^2 = 64$. This intensity which is for a white surface, multiplied by $\frac{1}{2}$, the factor for blue, gives 32 actinos as before.

As a simple proof of the correctness of this result, a piece of slow tinting medium held within the spot of light near the surface of the cloth reveals a first appearance time of 2 seconds, which time has already been found to indicate 32 actinos of intensity for a blue surface, or 64 actinos for a white one (p. 62).

As a further illustration suppose a common lamp flame approximately 1 inch in diameter, illuminates a fair complexioned face at 8 inches distance; what is the actinicity of the face?

It has already been found (p. 54) that the average actinicity of a kerosene flame is 32 actinos and therefore according to the first rule: $\frac{1}{16M} \times 64$ (cone units) $\times 32 \times \frac{1}{2}$ (actinic factor of a fair complexion) $= \frac{1}{16}$, of an actino, the intensity of the face. Or by the second rule, $\frac{1}{4} \times 32 \div 8^2 = \frac{1}{8}$ and $\frac{1}{8} \times \frac{1}{2} = \frac{1}{16}$ of an actino, the intensity of the face as before.

To prove this result the incident light time is taken at $f/2$, at 2 inches from the flame (with the standard tinting medium, to save time), and

the tint is secured in 8 seconds. It would be 16 times this time or 128 seconds at $f/8$, the flame's convergence at the head, and 8 times this time or 1M seconds with the slow factor 8 tinting medium used in these calculations. Now since a 64 second first appearance time on this factor 8 medium indicates one actino of intensity for a fair complexion, a time of 1M seconds indicates an intensity of $\frac{1}{16}$ of an actino as before.

As an example of exposure and to illustrate the practicability of even small and comparatively weak artificial lights for portraiture suppose that this head be photographed on a plate whose speed is 64 seconds or one minute and with a lens working at 256 cone units, ($f/4$). On dividing 64, the speed of the plate, by $\frac{1}{16}$, the actinicity of the face, and this result by 256, the unit value of the full lens opening, a result of 4 is obtained, the time of exposure in seconds under these conditions. A bank of 8 gas light flames, working at 16 diameters of the flame from the subject would probably create about four times the above intensity and would be very practical for bust portraiture, if the most rapid plates and lenses were used.

CHAPTER V

UNIT SENSITOMETRY

THE SPEED OF EMULSIONS

AS has already been made clear the speed of an emulsion is defined as the time required for it to suffer an effect which is known as normal exposure (see chapter VIII) when it is exposed to a surface having an intensity of one actino and through a diaphragm having a convergent value of one cone unit. (Number 1 of the unit scale, $f/64$, or U. S. 256.) Test exposures under these conditions followed by purely normal development, say for example, a development of five minutes in rodinal and water in the proportion of 1 to 20 and at about 65° F., will make it possible to select, on examining the resulting negatives, the time of exposure which has created the normal effect. This exposure time is the speed of the emulsion tested.

It is a fact that in their daily practice many photographers use developing formulas much stronger than what might be considered normal, i.e., stronger than would be required for purely normal exposures. The chapter on development should be read (p. 120) before performing

the following experiment as it is preferable that purely normal development be given.

To arrange for this test those who use plates or the film pack should make a cardboard cut-off to shield three quarters of the plate and allow only one quarter to be exposed at a time. This is done as follows. Cut the cardboard just large enough to fit into the bellows folds as close as possible to the plate holder. Draw a straight line through the center of the cardboard both lengthwise and crosswise and cut out one quarter of it as thus indicated. With roll film a few whole exposures had best be devoted to the work as they can all be developed normally by the time method without cutting apart.

The subject to be photographed in this experiment is arranged as follows. On top of a table and about 8 feet from a window which faces the sky place a box at least a foot square and over it arrange a white sheet so that on one side of the box it will face the camera, which should be placed about 2 feet to one side of the window and as near the wall as is convenient to work. The top sash of the window should be let down and the lower half of the window covered with a black cloth. The side of the sheet facing the lens should be smoothed so as to present an evenly lighted surface without folds or wrinkles so that its actinicity can be measured with the standard meter as already explained. Near

this smooth part of the sheet should be placed some objects of various colors and textures, including if convenient, a medium gray, to aid in judging the correctness of the exposure and the gradation and latitude of the emulsion.

Now if a plate or a film pack is being tested place the cut-off in the camera close to the plate holder as explained, and with a large diaphragm in the lens, focus upon the sheet and other articles, confining the image of course to the quarter of the ground glass visible through the open corner of the cut-off. Should a roll film be tested point the camera by means of the finder and focus with the focusing scale or in the usual manner according to the construction of the camera used.

The camera and subject having been placed, there remains to establish the unit condition of actinicity and diaphragm and to make the test exposures. The experiment should be performed on a clear day, as clouds, passing before the window, would vary the actinicity of the cloth. Now with the standard tinting medium in the meter, expose to the white cloth and ascertain the first appearance time of its light. Care should be taken not to shade the area which is being measured by holding the meter between it and the light. The meter may be held somewhat at an angle to the cloth so long as the smoothed part of the latter completely fills the $f/1$ opening as has already been explained in

the directions for using the meter (p. 38). Should the meter time prove to be 8 seconds as in the writer's present experiment, then as a trial cover about $\frac{7}{8}$ of the window opening with a dark cloth or such portion of it as will reduce the meter time of the sheet to 64 seconds, thus securing a one actino intensity. Care should be taken that a 32 second exposure *does not* create the tint but that one of 64 seconds does so. When this condition is obtained the cloth may be said to have an actinicity of one actino.

Now on placing the unit diaphragm in the lens ($f/64$ or U. S. 256), which is the other necessary constant condition, the test exposures may be made. After each exposure, when using the cut-off, remove the plate holder and turn the card to expose a different corner of the plate.

The speed of nearly all films happens to be 8 minutes or 512 seconds and taking this speed as a guide, the modern fast plate being considerably faster than this and having less of the quality of endurance as to be explained, it may be judged that test exposures of 16, 8, 4, and 2 minutes will reveal a correctly exposed section. If however the plate being tested is known to be one of the fastest, then these exposures may be 4, 2, 1, and $\frac{1}{2}$ minutes respectively. By normal development, the importance of which has already been emphasized, one of these sections will be seen to have had the correct exposure and the time of exposure given to that

particular section will be the "speed" of the emulsion tested.

It is clear that by such a method as that outlined the worker is enabled to select according to his individual taste or judgment, the speed for the emulsion. While one worker would select the exposure which gave plentiful detail and softness another might select that which tended to create a more decisive series of tone steps. One might say, for example, with regard to a certain film, "I like best the effect which corresponds to an 8 minute speed in that film" while a fellow worker might class that film as having a speed of 4 minutes.

THE METHOD AS PRACTISED

The foregoing method of reducing the actinicity and diaphragm to unity has been given to make clear in a simple manner the theory involved in measuring the speed of an emulsion. In "speeding an emulsion" in practice, however, it is unnecessary either to alter the strength of light on the subject or to close down the diaphragm to unity.

Suppose that it be desired to make test exposures say of 8, 4, 2 and 1 minute duration under unit conditions of actinicity and diaphragm. All that is necessary is to observe that the exposures given to a surface of any actinicity and with any diaphragm in the lens are equivalent to those unit condition exposures which it is

desired to give. For example should the light on the sheet when first measured in the full light of the window have measured 8 actinos, then the series of unit test exposures of 8, 4, 2 and 1 minutes which it is desired to give under unit conditions are reduced to their equivalent exposures, still with diaphragm one of the unit scale in the lens, by dividing each of the series by 8, the actinicity of the surface in actinos. The series becomes then the intervals of 1, $\frac{1}{2}$, $\frac{1}{8}$, and $\frac{1}{16}$ minutes, or better — 64, 32, 16 and 8 seconds. Should it be desired to shorten the exposures still more they may be divided by the number of any diaphragm used. For example if the 4 unit instead of the 1 unit diaphragm be used these exposures would be reduced to one fourth of those last given or to 16, 8, 4, and 2 seconds respectively.

A very convenient method is to divide 64 by the actinicity of the surface photographed, when the quotient will be the number of the unit scale diaphragm, which if used will allow the test exposures in minutes to be given in seconds. For example suppose that the surface used in the test measure 16 actinos; dividing 64 by 16 is obtained 4 and should the 4 unit diaphragm be used ($f/32$) the test exposures in minutes may be reduced to the same number of seconds, in this case the test exposures of 8, 4, 2 and 1 minutes being reduced to 8, 4, 2 and 1 seconds. This is for the reason that the combined condi-

tions are 64 times as fast as unit conditions, the 16 actinos of the surface photographed being 16 times as fast working as 1 actino and the 4 unit diaphragm 4 times as fast as the 1 unit diaphragm; the total greater rapidity is therefore 16 times 4 or 64. Therefore for each 64 seconds or 1 minute of the desired unit test exposures there will suffice 1 second under the faster conditions. Should the intensity be 8 actinos and the diaphragm 8 units, or the actinos 32 and the diaphragm 2, the result would of course be the same.

The reader should understand fully that *every normal exposure* (once the speed of an emulsion is found) *is equal to the speed time exposure of that emulsion under unit conditions of light and diaphragm.* For example should it be found that the speed of an emulsion be 8 minutes, every normal exposure is equal to 8 minutes exposure with unit intensity and unit diaphragm. This has already been explained and will be made still clearer by the two following examples.

Suppose that a plate having a speed of two minutes be used to make a short exposure of a running horse of average color; that the day is clear and the sun high and that another similar plate be used to make a long exposure of the interior of a room. It will be shown that these exposures when reduced to their equivalents with unit intensity and unit diaphragm con-

ditions, are exactly equal chemically. In the table of one unit actinicities to be used in practice (p. 143) it will be seen that an average view is considered as having 64 actinos of intensity when the p.o.p. time of the incident light is one second and since under the conditions mentioned the time would be $\frac{1}{8}$ of a second, the actinicity of the subject must be 8 times 64 or 512 actinos. The exposure with the 1 unit diaphragm would therefore be $\frac{1}{512}$ of 128 seconds, the speed of the plate, or $\frac{1}{4}$ second. Now should diaphragm 256 unit scale, or $f/4$, be used, the exposure will be $\frac{1}{256}$ of $\frac{1}{4}$ second or $\frac{1}{1024}$ of a second. Therefore an exposure of $\frac{1}{1024}$ of a second to a surface having 512 actinos of intensity and with a 256 unit cone in the lens is equivalent to an exposure of 128 seconds with unit conditions of intensity and diaphragm.

The other example as already stated, is that of a room interior which is given 8 seconds with the 8 unit diaphragm ($f/22$), the brightest part of the wall having measured 2 actinos. Had the wall measured only one actino the exposure with the same stop would have been 16 seconds instead of 8, and had the one unit diaphragm been used instead of the 8 unit one the exposure would have been 8 times 16 seconds or 128 seconds which, like the previous fast exposure, is seen to be equivalent to the speed time exposure with unit conditions. It is evident therefore that the two plates in the examples given

Plate VII—"THE WOOD'S SOFT LIGHT"

suffered approximately the same chemical exposure.

Any normal exposure multiplied by the unit number of the diaphragm used and then by the actinicity of the subject in actinos gives the speed-time of the emulsion used. It must also be true therefore that the speed-time divided by any two of the three factors of diaphragm, actinicity and exposure, will give the remaining factor.

Algebraically the relation is simply expressed by the equation $t = \frac{T}{aI}$ in which t is the time of exposure in any case, T the speed-time of the plate used, a the aperture in unit cone value, and I the actinicity of the light source.

Should the worker prefer he may proceed with the speeding tests on the basis of the author's suggestions regarding speed in the back of the book. The foregoing experiments are recommended however since by performing them one cannot but arrive at a full understanding of the truths involved. In regard to the speeds as suggested, should the exposures after trial seem in the judgment of the worker to be rather under normal the speed may be considered as twice the time used in the experiment. On the contrary, should they seem to be over-exposed then the speed-time may be considered as one half of that tried.

THE LATITUDE OF EMULSIONS

The latitude of an emulsion is its capacity to render in perfect gradation different degrees of actinicity in the same subject. An emulsion is said to have great latitude when it will register greatly differing intensities and to be "hard" on contrasty when it will register comparatively little actinic contrast or when a little actinic contrast in a subject suffices to fill, or fully utilize, its gradation capacity.

The latitude of an emulsion is indicated theoretically by the relative length of the straight part of the "characteristic curve" of the emulsion as described in Chapter VIII (p. 105). By trial the fractional part of an emulsion's correct speed-time exposure may be found which will suffice to create a just clearly visible deposit in the emulsion after normal development. Such an exposure may be known as a *one inertia* exposure since by normal development it only suffices to overcome once, so to speak, the inertia of the emulsion. The number of times that the normal or speed-time exposure is greater than the one inertia exposure, may be used as a factor to express the latitude of any emulsion. For example should the normal speed-time of a certain plate be 2 minutes or 128 seconds, and an exposure of 8 seconds under the equivalent of unit conditions, suffice to show a least discernible deposit after normal development (one of 4 seconds revealing no deposit)

then 8 seconds may be known as the *one inertia exposure* for that emulsion and the latitude of the emulsion would be 16 since 128 seconds divided by 8 equals 16. Expressed in other words, that emulsion is found to endure normally a 16 *inertia exposure* since the normal or speed-time is 16 times the one inertia exposure. Such an emulsion would be contrasty, as the modern fast emulsions will endure a 32 or 64 inertia exposure (p. 118).

Exposure may be comprehended as the act of overcoming the inertia of an emulsion a greater or less number of times, an over-exposure doing so too many and an under-exposure too few times or not at all, while a normal exposure overcomes the inertia the correct number of times thus producing the desired effect in the negative with normal development. The application of this idea of contrast in emulsions is obvious. A plate having say a contrast of 1 to 32 by this method would render in intermediate tones in the picture all surface actinicities in the subject from just under the maximum (which is treated as the objective point in the unit method) down to $\frac{1}{32}$ of the value of that maximum.

On developing snap shots made by the novice in the shade or in any too dull light it frequently happens that the brightest parts of the subjects have impressed themselves on the emulsion only just enough to develop a visible deposit. In many such cases those planes have

received approximately but a one inertia exposure and as an average emulsion was used, i.e., that of roll film of which none are made of a very "hard" quality, it would have required from 32 to 64 times the exposure actually given to have prepared the latent image for development into a normal negative.

The latitude 32 may be considered as the average and is that of the usual modern fast plate. Films on the whole have greater endurance probably by reason of the entire absence of glass in their construction, which makes them naturally of a "non halation" quality. The latitudes 16 and 8 are "hard" or contrasty and of 4, is extremely contrasty. It is doubtful however if the latter degree of contrast exists in any emulsion.

The average and soft emulsions are to be used for the average sunlight view and for portraiture and all subjects having ordinary contrasts. The hard emulsions are used more especially for photo-mechanical or process work in which it is required to get extreme contrasts in copying flat prints or to obtain effects in black and white as in the production of white lines on a dark ground or the reverse. However when the illogical desire for speed has run its course among photographic workers and emulsions are selected purely by reason of their quality or latitude, which is simply their adaptability for subjects of certain known contrasts, then these

hard emulsions will be used much more for all those subjects which have but little contrast such as bird's eye views and copies in general.

On these hard emulsions a little more than the correct exposure seems, on development, quickly to clog the film and spoil the gradation steps completely, they having but little endurance. These emulsions seem usually to be quite thinly coated and to develop much more rapidly than emulsions of more latitude or softness and care should be taken therefore not to over-develop them. The normal developer should be diluted by nearly an equal quantity of water or the time of development be reduced to nearly half. Since the latitude of these emulsions is so limited, it is evident that more than the usual care should be exercised in order to arrive at the correct exposure.

As has already been explained, it should be known of any emulsion that its normal exposure is one which overcomes the inertia of that emulsion, 8, 16, 32 or 64 times as the particular emulsion may require. It will thus be known how much under-exposure may be given with any emulsion when it is desired in that manner to decrease the detail in the weak or shaded parts of a well contrasted subject or to increase the tone contrast when photographing a subject of minimum or under-normal actinic contrast as is explained in the following chapter.

CHAPTER VI

ACTINIC CONTRASTS

COMPARISON OF DIFFERENT ACTINICITIES

THE actinicities of different planes or surfaces in nature should be observed and contrasted in order that one may comprehend practically the purely quantitative nature of actinic values. We have but to observe at any time that which confronts our eyes to comprehend that the field of vision is filled with a miscellaneous assortment of objects and that the nearest ones outline their edges against the surfaces of those next beyond them, etc. One may take careful note of all the objects which confront the eyes and find that each one has its observable and measurable value or rather values, since it is rare indeed that the whole surface of any single object is of equal intensity throughout. There are considerably more than a dozen easily definable causes of actinic contrast in the visual field and the study of these causes in connection with the characteristic effects which they produce should develop the powers of observation to a great extent and it seems to the author that such a study would be as beneficial in pure art instruction as in the study of photography.

Entirely aside from the purpose mentioned in the preceding paragraph the photographic worker must study actinicity and actinic contrast since this alone is the cause of the gradation in the negative upon which he must depend for the tone scale of the finished photograph. Actinicity is both the foundation and the keystone of the photographic arch; the foundation because it is the active energy upon which the process rests and the keystone because the study of it sharpens the conception of light effects in nature by making their definite cause understood. Through a knowledge of this energy the photographic worker may obtain with certainty those effects which as an artist he may conceive and wish to produce (pp. 102, 139, 141).

The author believes that too small a percentage of those who pass through the art schools are ever heard from as artists of merit and it is recognized by all teachers of art that there is a point in the progress of the student beyond which no teacher can help him. This is when the pupil has learned all that he can of technique as taught and must go out into the presence of nature and develop his own powers. At this point art education needlessly ceases to help and there are sent out from the schools hosts of students who are unable to understand the exact cause of the simplest light and shade effects in nature and in whose minds therefore cannot be developed that direct *connection with*

nature which is the one thing now needful. These students cannot grow in the direction in which true artists must develop and they usually either cease their art endeavors or drift into the work of copying. From such students are supplied the army of copyists which fill the present day "enlarging houses." The author has known copyists of real merit who, working on their own account, obtained high prices for their products but who were entirely dependent upon photographs from which to paint. To see a painter thus dependent upon photographs, usually gross conventionalities made by a workman without the least artistic conception, arouses in the writer a conviction that there is something quite fundamental entirely lacking in art education. In spite of his undoubted higher abilities such an artist is, in a sense, by the ignorance of certain truths of nature, degraded to a point below that of the photographic artisan.

The author's first inquiry into the methods of the art schools was induced by the desire to know why these artists, or copyists, who had studied in the art schools could not place a subject by a window and through a knowledge of light values, construct a "living picture" which might serve, for example, as an artistic tableau or as a subject for photographic exposure, the result of which exposure might be an artistic or at least a photograph of correctly graduated

tones. As a comparison it may be said that the knowledge of harmony never made a musician. But is it not also true that it has helped thousands of students with a natural talent for music to discover themselves and to grow? What could have hindered musical growth in the past more than the lack of the discovery of the octave, the different scales and those laws of harmony, which form the basis of the study of music?

Science is nothing more than classified truth and the quantitative character of actinicity and the possibility of making exact measurements of it provides us with a scientific basis for the establishment of a system of study whereby the student of art may arrive at a somewhat full knowledge of the *actual causes* of the beautiful effects of "light and shade" in nature, since under ordinary conditions *actinic* gradation in any subject is usually accompanied by a *visual* gradation and the two may for the most part be traced to the same source or cause. To know the cause of a beautiful light effect and to be able to reproduce it at will cannot but increase the interest of the painter or photographer, leading him to a closer observation and appreciation of nature which is the true source of his inspiration. The author cannot develop in this book his system for the study of the light effects of nature through the analysis of their causes but hopes to do so later in another volume.

As has been impressed, however, the fact of

actinic contrasts should be made very familiar to the photographic worker through measurements and comparisons. The sun at 32,000,000 actinos against a sky of 512 actinos presents two adjacent surfaces with a contrast of 1:64M, the sun being intrinsically about 64,000 times as intense as the sky. A newly painted white building in direct sunlight is about twice as intense as the sky. A head placed about the width of a window in from one of its casings toward the center of an ordinary room will be only from $\frac{1}{32}$ to $\frac{1}{64}$ as intense on the shaded as on the lighted side. When a reflector is used so as to balance this contrast the darker side will have from $\frac{1}{4}$ to $\frac{1}{8}$ the intensity of the lighter. This degree of contrast introduces the half tones of the picture and the detail in the shadows of the hair and clothing. Out in the open the sunny side of an object of uniform color throughout, will be only about 4 times as actinic as the shady side.

Any two actinicities may be compared on measuring that of each by any of the methods given in the problems. But when contrast alone is desired and not actual values, it may be found, provided the surfaces be of the same color, by tinting any sensitive product in the light near the brighter surface, to any convenient degree, and then observing the number of times longer required in the position of the weaker surface to secure the same tint. For example in taking

the contrast between the sunny and shady side of some object out in the open, using the contact opening in the back cover of the meter book (p. 35) and a strip of p.o.p., expose to the sun and sky for one second then change the position of the strip of paper and on the shady side of the body expose to the sky alone long enough to bring the tint to the same depth. Four seconds will probably be found sufficient. Sunlighted subjects are not, as is usually supposed, excessively contrasted, especially in the open. The lighted and less lighted, or as usually termed the lighted and shaded areas are however divided by very sharp lines and the impression of great contrast in such subjects is generally derived from the appearance of negatives made from them which have been under-exposed and over-developed.

From the standpoint of the photographic artisan each actinic value throughout the different planes of a subject is as "a tool in the hand," with which he must with absolute foreknowledge, create the tone scale from high-light to deepest shadow in his resulting picture. This he must do by first conceiving what result or tone scheme he desires, then by seeing that the actinic gradations agree with this scheme after which the tool, which is the actual exposure, must be applied, so as to obtain the effect desired, as understood from the definition of the term "correct exposure," given on page 14. Actinicity

must therefore be studied as a fundamental element in the photographic process just as are now considered in a quantitative sense the facts of diaphragm opening, speed of emulsion and exposure time, and these latter are in fact less fundamental than actinism, since they cannot be properly comprehended nor applied except in their relation to the actinicity and contrast of the subject photographed.

The actinic contrast of nature, as it presents itself ordinarily, is frequently beyond the capacity or latitude of any emulsion to register. In view of the writer is a white cloud having an intensity of at least one thousand actinos. The inside casing of the window through which that cloud is observed measures but one actino. (In the average room it would measure only from $\frac{1}{8}$ to $\frac{1}{2}$ an actino.) It has been found that no emulsion has so great a latitude as this. But few if any emulsions can normally register contrasts greater than 1 to 64 (p. 118).

In the case of the cloud and the window casing mentioned, if an emulsion having a latitude of 1 to 64 be used and the cloud be made to overcome the inertia of the emulsion 64 times, an intensity in the same view which would overcome the inertia only once must be at least $\frac{1}{64}$ as actinic as the cloud, or must have 16 actinos of intensity and the window casing with its one actino could only do $\frac{1}{16}$ part of the work necessary to overcome the inertia once. On the

Plate VIII—AN OUTDOOR PORTRAIT

other hand should the exposure be increased 16 times so as to give time for the casing to overcome the inertia once, then the image of the cloud would produce 16 times the exposure that the emulsion normally should endure. The sky by the side of the cloud would also have had an exposure equal to about 8 times the normal endurance of the emulsion and the cloud and sky would be no longer distinguishable from each other in the opacity planes of the negative. Furthermore the long duration on the emulsion, of the images of the cloud and the sky, 16 or 8 times as long as the endurance of the emulsion, would constantly illuminate the whole interior of the bellows and furnish sufficient light reflected from its sides to overcome the inertia evenly over the whole emulsion. This uniform exposure would develop as "fog" in the negative. It is extremely important therefore that the worker recognize the fact that too great contrasts are to be avoided since they are beyond the capacity of emulsions to register.

THE RELATION OF ACTINIC GRADATION TO THE TONE STEPS OF THE PICTURE

It is necessary now to illustrate the effect of the different actinic planes of a subject on the opacity steps of the negative as brought about by different degrees of exposure. Let a, b, c, d, and e (fig. 8) represent the different areas or

parts of a subject, A, which confronts a lens, L, and a′, b′, c′, d′, and e′ the corresponding image planes on the plate A′ on which the subject is supposed to be photographed. Suppose the planes a, b, c, d, and e of the subject have, as marked in the figure, 16, 8, 4, 2, and 1 actinos of intensity respectively. Suppose also that the plate used has a latitude of 1 to 16 and will therefore, with normal exposure, reproduce this subject with full tone gradation. In this experiment it is irrelevant whether or not there results a so-called technically perfect printing negative as described in chapter VIII, as this depends purely on the latitude, i.e., hardness or softness of the medium to be employed in printing the picture from the negative and a correct negative for any medium is obtained simply by developing its most opaque part of the proper density as compared to its least opaque part. What is being studied here is of an entirely different nature and refers solely to the latent chemical preparation of the emulsion to develop into a negative with a predetermined and desired gradation. If the *latent image* be prepared in an emulsion as just explained it is impossible as well as unnecessary to alter the relation of its density steps (see chapter VIII). As explained, such a latent image may be made into a correct negative for any printing medium by the correct degree of development or after manipulation.

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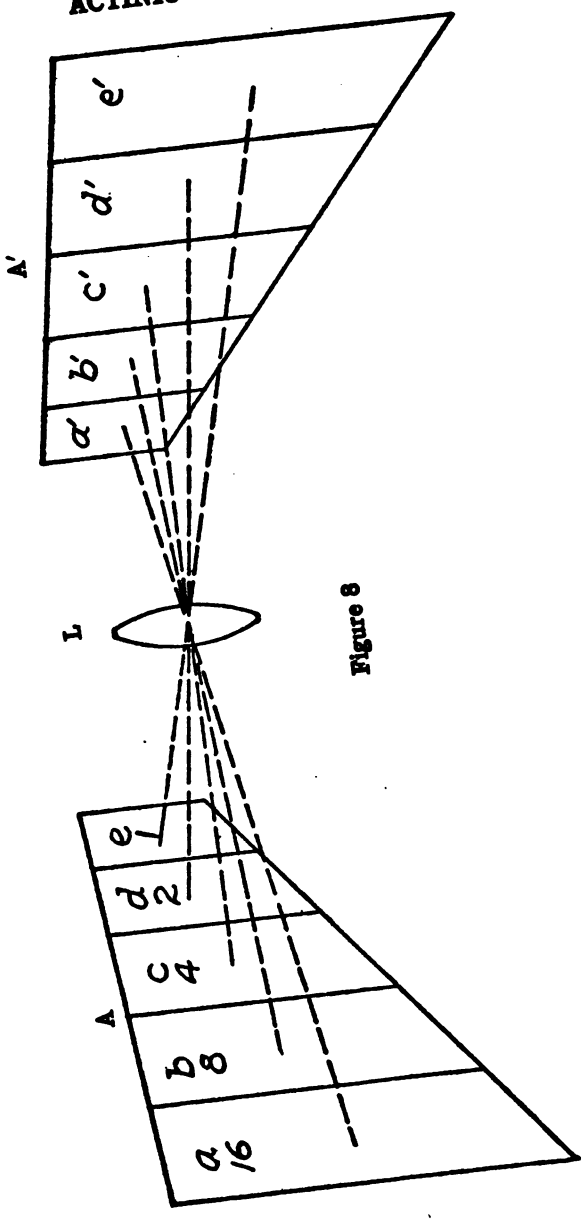


Figure 8

With normal exposure to this subject under the conditions mentioned, the area of greatest intensity would be made to overcome the inertia of the plate 16 times and the planes b, c, d, and e would do so 8, 4, 2, and 1 times respectively. Even the area e, of least intensity, by overcoming the inertia once, would be detailed and would be represented by the next to the deepest tone in the subject, since it would still be higher than that of the adjacent background which will be considered as being without actinicity or in darkness. What is to be observed here is that all the six areas of different intensities (including the background) are reproduced and well differentiated in the resulting negative and will be seen in well separated tone steps in the finished photograph, provided of course the latitude of the printing medium and the contrast of the negative agree with each other.

It will now be shown how under-normal exposure (see chapter VIII) prepares the way for a greater contrast gradient in a negative and in its resulting picture. Since in the foregoing normal exposure the plane e only overcame the inertia of the emulsion at e′ once, it is evident that on giving a half normal exposure this plane would be excluded from appearing in the negative, by normal development, while the plane d would overcome the inertia but once and would therefore take the lowest tone step above

Plate IX — IN CARNIVAL DRESS

the darker and undetailed backgrounds. The plane a would create an 8 inertia exposure at a′. Including e′ with the background as the lowest tone there are now but five tone steps instead of six in the picture. Now by slightly longer development or by intensification this plate may be carried to the same opacity at a′ as the previous one had and the extreme light and dark tones would be the same in each picture since the lowest tone is so-called "clear glass" or simply the unexposed and undeveloped gelatin emulsion fixed out. But since there is one less tone step in the picture *these steps must of necessity be farther apart than in the previous negative.* Again, should the exposure be but $\frac{1}{4}$ normal so that the plane a would overcome the inertia at a′ but 4 times, b and c would do so but twice and once respectively and the planes d and e would both disappear into the background and be excluded from appearing in the picture, since the exposure has not been sufficient to allow the intensity of either of them to overcome the inertia of the emulsion even once. This $\frac{1}{4}$ normal exposure, by longer development or intensification, may still enable the emulsion at a′ to be carried to the same opacity as in the first negative but its resulting picture would show but 4 tone steps, i.e., those of a, b, and c and the clear gelatin. If the highest and lowest areas are made to have the same opacity contrast as previously, then it is clear that the

resulting tone steps must be still farther apart than in the last negative, there being one less step. Continuing the experiment, an exposure of 2 inertias at a′ would include only the plane b with it in the negative as those of c, d and e would drop in with the background. This exposure however would be difficult to develop or intensify to the same opacity as the first one, although it might be carried to sufficient opacity to produce a print on a contrasty printing medium. There would be but 3 tone steps in the resulting picture.

It is seen therefore that *too* little exposure fails to furnish sufficient chemical base, so to speak, for the building up of the desired opacity and that when carried to extremes it defeats the very end in view. The average emulsion with a latitude of 1 or 16 or 1 to 32 requires at least a 4 inertia exposure to provide sufficient base upon which to procure a practical degree of opacity. On a hard emulsion, one whose latitude is say 1 to 8, a 2 or 4 inertia exposure will produce sufficient chemical change to make a negative of considerable opacity. Such an exposure should not be given except in the case of a subject having a minimum or very little actinic contrast such as will now be explained.

Plate X — CLOTH TEXTURE

CHAPTER VII

CLASSIFICATION OF SUBJECTS AS TO THEIR ACTINIC CONTRASTS

SUBJECTS OF MINIMUM CONTRAST

BIRD'S eye views are usually of this class as well as flat surfaced subjects which have but little tone or color gradation and hence little actinic contrast, as for example the evenly toned tin type or ferrotype, the daguerreotype and also photographs which have little tone contrast and which are to be copied, as well as all subjects which are to be photographed for their texture alone (see plate X). Should however a photograph or any flat surfaced subject have a full tone contrast as nearly from white to black, such a subject must be classed as of normal or nearly normal contrast. Should the inherent actinicity of any subject differ to a considerable extent in its different areas, as the hair, face and dress in a portrait subject, no lighting whatever can make of it a minimum contrast subject.

Every worker who does not deviate from the use of the modern fast emulsions must have encountered certain kinds of subjects which it

seems impossible to render with brilliancy or well separated tone steps, even when it is desired to do so. By giving thought it will probably be found that these are the minimum contrast subjects now being discussed, of which plate IV is a good example. (It is evident that an exterior of minimum contrast would ordinarily be void of interest. The area of grass without flowers on the left of the plate represents such a subject.) From such subjects and with the emulsions mentioned, under-exposure with normal development gives thin flat negatives while normal exposure with normal development gives good density but little gradation. When it is considered that such a subject may easily have an actinic contrast between its brightest and darkest parts of only 1 to 2 and that the emulsion used has the capacity normally to render contrasts of probably 1 to 32, this tendency to flatness is not a matter of surprise. The wonder is that the contrasty emulsions with the latitude as low even as 1 to 4 or 1 to 8 have not been utilized more for the reproduction of these subjects of little actinic contrast to which they are by their nature so perfectly fitted.

SUBJECTS OF UNDER-NORMAL CONTRAST

Such subjects should be given about one half normal exposure. Of this class are ordinary exteriors on cloudy days, unless the varied form and color of the objects in the view tend to in-

crease the contrast. This subject is illustrated by plate V.

Exteriors in sunlight may be of this class should there be no close objects nor very strong color contrasts and especially should the point of view be in nearly the same direction from the subject as the sun. As mentioned under the last head, flat subjects of good contrast, as full toned photographs, engravings, etc., belong to this class of subject. The usual out-of-door portrait, in the shade of walls or trees is also of this nature as well as average interiors from which strongly lighted parts are excluded. Any portrait subject may be in this class if the lighting be quite soft or produce little contrast. Such subjects have an actinic contrast approaching 1 to 8 and emulsions of similar latitude would render them in full tone gradation with normal exposure. With the ordinary soft emulsions however practically the same result may be obtained with half normal exposure and rather more development or intensification.

SUBJECTS OF NORMAL CONTRAST

A subject under this head is defined as one whose actinic contrast does not differ greatly from 1 to 32, and an emulsion of equal latitude will of course be normal for such a subject and with normal exposure the full scale of tones will be obtained in the resulting picture. Sunlighted exteriors in which the greater area is

in the shadow, as when the observer looks somewhat towards the sun, and also foreground subjects in sunlight are among the normal subjects as shown in plate VI.

On cloudy days or when the sun is below the horizon a subject may reach this degree of actinic contrast should there be some objects of broken form or with planes extending in different directions and some of these planes facing downward away from the direct light of the sky, as shade trees, animals, houses with covered porches, etc. If one includes white clouds in the analysis of an exterior subject it is usually, except in the cases of very open or bird's eye views, to be classed as having over-normal contrast. When in an interior there is included some rather strongly lighted parts somewhat adjacent to the light source, normal or even over-normal contrast may be obtained at will.

Portraiture in general presents this normal class of subjects. This is the highest form of photographic subject not only from the artistic and aesthetic point of view but from that of the artisan as well. This is for the reason that while other subjects generally have their lighting and contrast laid on them, so to speak, by nature, and are usually analyzed and photographed as found, the portrait subject is free or movable and its lighting contrast when photographed, if perchance it be the result of forethought, must be the conception and creation of

the worker. This should be the case always but unfortunately mere accident too often determines the lighting of the amateur portrait while a cold conventionality characterizes the work of those professionals who depend for their light and shade effects upon the automatic action of their studio light (pp. 87, 139, 141). Portraits of normal contrast are shown in plates VII, VIII, IX and XIII.

SUBJECTS OF OVER-NORMAL ACTINIC CONTRAST

The extreme subject of this class is usually a combination of interior and exterior as illustrated by the example of the cloud and the window casing on page 93. Such subjects should be avoided when possible. If the contrast is not too abnormally great however, much may be done to render such subjects in good gradation in spite of the necessary overexposure of the brighter parts, by exposing just enough to overcome the inertia of the emulsion one or two times where the darker intensities impinge and then developing but one half the normal time in order not to build up excessive opacity and contrast in the negative. The usual error is to over-develop such exposures thinking to bring out more detail in the shadows and in doing so the opacity contrast is so increased that the shadow details are usually eliminated or "burned up" in the effort to obtain the texture or detail of the high lights in printing a picture

from the negative. If however the exposure be made by measurement so that the lowest plane *in which detail is desired* is made to overcome the inertia as stated, this latent image or effect, lying as it does on the outer surface of the emulsion, will develop very soon after the developing solution is applied and without any modification of the usual method except to avoid too great opacity in the most exposed parts by reducing the normal time of development as has already been stated. Or the negative may be normally developed and the too opaque parts reduced locally after the negative is fixed, as will be explained in another chapter (p. 120). It is evident that for such a subject an emulsion of the greatest possible latitude should be used. The use of film, and non-halation and double coated plates aid in securing such subjects. Plate XI illustrates such a subject photographed on film with the sky and field reduced locally.

CHAPTER VIII

THE HURTER AND DRIFFIELD SYSTEM

INTRODUCTION

A NUMBER of years ago two Englishmen, Messrs. Hurter and Driffield, made a rather complete investigation of the photo-chemical properties of a photographic plate, the immediate object of which was to provide the amateur with a method of determining the speed of the plates used and to influence them to substitute methods of scientific precision for the wasteful and disappointing guess-work methods generally practised. Their work which really began with the introduction of the gelatin dry plate and continuing for a number of years is finally published in a very concise and readable form in "The Photo Miniature," Nov. 1903 (Vol. V, No. 56).

It is clear that the practice of photography must resolve itself into two parts — the purely artistic and the distinctly scientific. It is for the artist to show the picture — for the scientist to reproduce it. It is then to the method of truthfully representing natural objects with special attention to the various intensities of light and shade that we shall direct our attention.

A PERFECT NEGATIVE

The authors defined "a technically perfect negative as one in which the opacities of its gradations are proportional to the light reflected by those parts of the original object which they represent," and their research showed that such a relation may exist but only when a plate has received correct exposure, and also a proper time of development. The reason for this definition is clear when we remember that the negative is only a printing screen for use in making a positive picture and that the brightness of any spot on the print is directly proportional to the opacity of the corresponding area of the negative.

In the above definition the term "opacity" is assumed to be the reciprocal of "transparency," this being the fraction of the incident light that a layer transmits. Thus the transparency of a film of reduced silver which transmits one third of the light incident upon it is $\frac{1}{3}$, and its opacity is 3. If the term density be applied to the actual quantity of silver deposited per unit area, it can be shown that density forms a convenient transition between opacity and the "exposure." In this discussion "exposure" will be understood to mean the product of the illumination expressed in proper units by the time during which the action lasts.

This is clear from the following discussion.

Suppose we have four areas a, b, c, d on some negative on which the silver deposit per sq. cm. occurs in the ratio of the numbers 0, 1, 2 and 3; these then may be taken as the several densities of the areas, and are in arithmetical progression.

Suppose now that the thickness of the area b be such that $\frac{1}{4}$ of the incident light is transmitted. As area c has twice as dense a silver deposit as b, the light transmitted through it will be just as if c were made up of two superposed layers each like b. In this case the light incident on the under layer being $\frac{1}{4}$ that incident on the upper, the two layers together will transmit only $\frac{1}{4}$ of $\frac{1}{4}$ or $\frac{1}{16}$ of the initial amount. So the areas transmit respectively $a_{\frac{1}{1}}$, $b_{\frac{1}{4}}$, $c_{\frac{1}{16}}$, and $d_{\frac{1}{64}}$ of the quantity of light incident on each. As these numbers represent the transparencies, their reciprocals will denote the opacities or a1, b4, c16 and d64.

Now we started with the densities in arithmetical progression 0, 1, 2, 3, and have found the corresponding opacities to be in geometrical progression 1, 4, 16, 64, from which the following relations are evident, viz. $4^0 = 1$, $4^1 = 4$, $4^2 = 16$, $4^3 = 64$. This is the same as saying that the density is proportional to the logarithm of the opacity, since $0 = \log_4 1$, $1 = \log_4 4$, $2 = \log_4 16$ and $3 = \log_4 64$, the base of the system depending on the scale of contrast chosen in the areas.

Had area b been so thin as to transmit $\frac{1}{2}$ the

incident light, the base of the system would have been 2 instead of 4; but still the opacities would have been in geometrical progression, the corresponding densities being in arithmetical progression — a logarithmic relation.

It is clear then that the densities of a series of areas on a negative are always proportional to the logarithms of the corresponding opacities, but if the negative represent proper tone gradations, the additional condition must hold, viz., the opacity must be proportional to the exposure. Therefore for a technically perfect negative the density should be proportional to the logarithm of the exposure. Thus we see that the law of true tone gradations is expressed by saying that the quantity of reduced silver per unit of time at any point in a negative is proportional to the logarithm of the light intensity incident at this point. Let us see under what conditions this is possible.

THE CHARACTERISTIC CURVE

The above proposition was experimentally demonstrated in the following way. Thickly coated slow plates were found best for experiment. Upon one of these a series of exposures was made beginning with one second and doubling the time at each successive exposure. The times of exposure with a constant source of illumination were thus in geometrical progression. After development the density resulting from each exposure was determined and its

value with the corresponding exposure plotted as shown in the curve, figure 9, the geometric series of exposures being laid off equidistant on

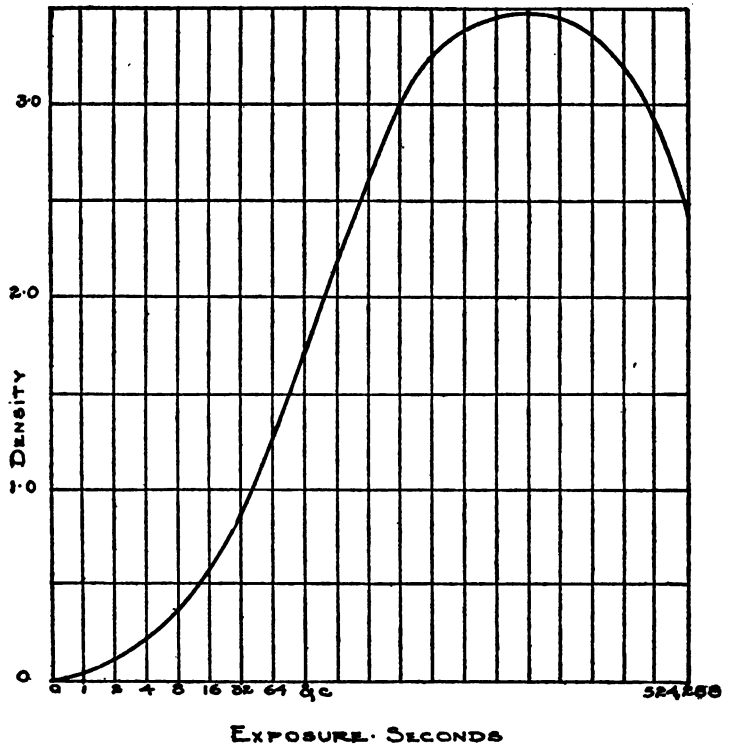


Figure 9. Hurter and Driffield's "characteristic curve" illustrating their theory of exposure

the horizontal axis. This curve is to be known as the "characteristic curve" of the plate. On examination the curve is found to consist of four distinct parts, corresponding respectively to the exposures 1 to 32 seconds, 32 to 1024 seconds,

and two other parts corresponding to greater exposures still. It will be noted that the second part is a straight line which signifies that the vertical distances are proportional to the horizontal distances, but the vertical distances which represent the densities actually measured are in arithmetical series while the corresponding horizontal distances are made to represent numbers in geometrical series, these numbers denoting the exposures. Thus the densities are seen to be proportional to the logarithms of the exposures in this part of the curve, and therefore this part of the curve expresses the law of true tone gradations.

For exposures 1 to 32 seconds the density increases approximately with the exposure and would continue to do so for larger exposures but for the fact that the effect of the light can only result on the *unaltered* silver present at any instant, and this of course is gradually decreasing so that a second of exposure to a given light agent at the end of a minute would add a far less increment to the density than it would at the end of 5 seconds when there would be so much more unaltered emulsion to act upon. As then at first the densities vary as the exposures, the opacities will increase much more rapidly and the effect of printing will be one characteristic of an under-exposed negative, i.e., a too great contrast of light and shade.

Similarly it can be shown that the third part

of the curve corresponds to the period of over-exposure in a plate in which the growth of density in the brightest lighted parts is so slow compared to the exposure as to result in a plate of too little contrast. The more strongly lighted parts have become nearly saturated with altered silver and do not increase much in density with time, while the less lighted parts are still increasing rapidly with time. The result is obviously a flat negative.

The fourth branch of the curve corresponds to a period of excessive over-exposure resulting in a reversal of the image. This has been studied in detail by Nipher and others.

Referring again to the straight part of the characteristic curve it will be noticed that for the particular plate used, any exposure from 32 to 1024 seconds would have produced a technically correct negative. This range or "latitude" (see chapter V) is different for different plates and is taken into account in selecting a plate for a particular purpose. Further, to produce a properly graded negative the exposure must be within the limits assigned by the latitude. By no special method of development is it possible to change the *density ratios* on any particular plate. The *actual* densities at the different points of a plate are of course dependent on the kind of developer and the time of development, but not the *ratio* of the densities at any two points.

LAW OF CONSTANT DENSITY RATIOS

An important part of the work of Hurter and Driffield was the experimental demonstration of the statement made in the last paragraph, viz., that the ratio of the densities of any two areas of a finished negative is independent of development. A plate was exposed in three sections crosswise to a candle light placed a meter away, the first section being exposed $1\frac{1}{4}$ seconds, the next $2\frac{1}{2}$ and the third 5 seconds. The plate was then cut into three strips lengthwise, each strip therefore having on it three different exposures. They were then developed in the same solution for 4, 8, and 12 minutes respectively and the nine densities measured. From these the density ratios, the opacities, and the opacity ratios were calculated and all tabulated as shown below.

	1 Exposure	2 Density	3 Density ratio	4 Opacity	5 Opacity ratio
Strip No.1 .	1.25	.310	1.0	2.04	1.0
Developed .	2.5	.520	1.67	3.31	1.62
4 minutes . .	5.0	.725	2.33	5.30	2.59
Strip No. 2 .	1.25	.530	1.0	3.38	1.0
Developed .	2.5	.905	1.70	8.03	2.37
8 minutes . .	5.0	1.235	2.33	17.18	5.08
Strip No. 3 . .	1.25	.695	1.0	4.95	1.0
Developed .	2.5	1.140	1.64	13.80	2.78
12 minutes .	5.0	1.625	2.33	42.17	8.51

Plate XI — BLUEBERRIES

NEW

The density ratios of the three exposures for all periods of development are seen to be practically the same. The densities, the opacities and the opacity ratios all increase with the time of development. Since the exposures are as 1: 2: 4, it will be seen at a glance that the opacity ratios coming nearest to this are those resulting from the 8 minute development. It may be estimated that had strip No. 2 been developed about seven minutes the opacity ratios would have been about as 1 : 2 : 4, and this strip would then have been technically perfect as to its tone gradations, the several opacities being proportional to their exposures. Strip No. 1 is seen to be under-developed, while No. 3 is much over-developed.

Having exposed a plate correctly then Messrs. Hurter and Driffield conclude from the above results that it is equally important to develop it for the proper length of time. The authors explain however how this point of "correct development" must be modified in practice. On page 121 the present author shows that the point of correct opacity or correct contrast may as well be reached by means of reduction or intensification as by development only so long as the exposure has been correctly given. As has been made clear the straight part of every characteristic curve, whatever the time of development, indicates a direct proportionality between the density and the logarithm of the

corresponding exposure. The *slope* however is seen to increase with time of development, and there is only one slope for which the various opacities are so graded that the corresponding densities are proportional to the logarithms of them; i.e.— There is only one slope, or time of development which in any particular case will result in a technically perfect negative according to the definition. The trigonometric tangent of this particular slope may be called the "development factor" for the plate. Theoretically this should be unity and the slope should be 45°. Practically it may and must vary from this in any degree as required to produce negatives whose opacity will harmonize with the printing paper or other medium used and also to obtain in the picture special effects deviating at will from the full scale of tone gradations which is usually considered desirable.

MEASUREMENT OF OPACITY

Hurter and Driffield define opacity as "the optical property of a substance to impede the passage of light through it." On this definition the author of the present work suggests the following practical method for measuring and defining that property. In the sense of the definition it is seen that even clear glass has opacity, since, to an extent, it impedes the passage of light through it. A negative impedes the light by *reflection*, from both the outer and inner

surfaces of the glass, as well as by *absorption* and *diffusion*, yet the total amount of hindrance to the light is comprehended in photography by the one word "opacity."

Should a tinting medium be exposed to any light for one second and a tint be secured it may correctly be considered that the clearness of the atmosphere, i.e., its degree of opacity, in a sense determines the depth of the tint secured. Had the atmosphere been smoky instead of clear it is evident that the same tint could not have been secured in the same time. If for example the time required to obtain the same tint through the smoky atmosphere be five times that required through the clear atmosphere then it might very properly be said that the opacity of the former was five times the latter.

Opacities in general then, as those of the different planes of a negative or that of any substance not entirely opaque, may be conveniently referred to that of the ordinary clear air, the opacity being proportional to the time required to produce any given tint through the medium as compared to that required to produce the same tint through the air alone. If for example it required 8 seconds to secure a tint through some particular part of a negative which was secured in 2 seconds without the negative (through the air alone) then that plane of the negative measured may be said to have a rel-

ative opacity of 4. It must be noted that the opacity under consideration is that for the special kind of radiation used in photography. Thus some piece of deep blue glass may be optically quite opaque and yet have very low actinic opacity.

Comparative exposures for finding the relative opacities of different parts of a negative are conveniently made in an ordinary printing frame with a piece of black paper, having a small hole in it, placed between the plane to be measured and the tinting medium. By this means the latter may be examined from time to time as in ordinary printing in order that the tint secured may be made to match the temporary standard tint first obtained through the air. This temporary standard tint is very conveniently that produced by a one second exposure to direct clear sunlight or by 2 or 4 seconds to an open sky, as found necessary to produce some visible tint.

It is a fact easily verified by measurement that the clearest possible area of a glass plate negative, or of a film negative when measured with the glass upon which it is laid for printing, although consisting only of a layer of clear gelatin and its glass support has an opacity about twice that of clear air. The opacity gradient of a negative therefore never starts from zero.

Having measured the thinnest and thickest

parts of a negative its contrast factor may be found by dividing its greater opacity by the less. Should it be desired to obtain only the contrast factor between the two extremes of a negative, without actually measuring the several opacity planes then the temporary standard tint, the one to be matched, may be taken through the thinnest part of the negative instead of through the air alone. When this tint is matched through the thickest part of the negative the ratio of the corresponding tinting times will be the contrast factor of the negative measured.

It may be observed that the negative from minimum contrast subjects and from all exterior subjects are considerably more opaque at their thinnest areas than negatives taken in interiors, as portraits, etc. There are seldom seen in negatives of the former group, areas consisting of the so-called "clear glass" parts. This is owing to a greater general distribution of light throughout all parts of exterior subjects and to excessive reflections within the bellows. This explains why exterior negatives should usually on the whole be more opaque than those taken in interiors in order to obtain a desirable tone scale, as of course, since the thinnest parts are of considerable opacity, the thickest ones must be of proportionally greater opacity to secure the usual contrast.

The importance of making a negative agree in its opacity contrast with the degree of hard-

ness or softness of the printing paper or other medium has already been emphasized (pp. 15, 94). By making three prints from a medium negative, one on a very hard or contrast paper, another on one of normal gradation and another on a soft paper this truth should be fully appreciated and will need no further demonstration.

According to the chart on page 109 it is seen that the straight part of the curve includes the exposures of from 8 or 16, to 1024 inertias according to the present author's method of considering exposures. In explaining the characteristic curve Messrs. Hurter and Driffield explain (p. 108) that thickly coated, slow plates were used. However accurate it may be theoretically, that a one thousand inertia exposure of an emulsion is the maximum correct limit, this is certainly not true in practice with the emulsions generally in use, which, as I have stated, begin to show a dulling over of surface texture in the image when an exposure of 64 inertias has been given, even with the softest working emulsions now employed. It seems to the present author that the observation of the characteristics of developed spots of emulsion which have been exposed by direct illumination, as from a flame, cannot give the information which is required to enable us to use these emulsions for the purposes of practical photography, since the consideration of *texture rendering* does not enter and since it is here that the

effect of over-exposure is first looked for in actual practice. For this reason the "inertia exposure" method of considering the character of emulsions (p. 83) is recommended as the most correct and useful from the practising photographer's standpoint.

CHAPTER IX

NEGATIVE MAKING

DEVELOPMENT AND FIXING

IF photography be practised as taught in the method herein presented, i.e.— with due consideration to the actinicity of the surfaces photographed and with a knowledge of the inertia exposure to be given in each case, it may easily be realized that development is almost purely mechanical in its nature. This is practically true and in fact has been demonstrated in the previous chapter. The author, in the practice of home portraiture, works under vastly different conditions of light from hour to hour and uses roll film, never seeing an image on the ground glass, but because the light is measured in each case and a correct exposure given the development of these films are safely entrusted to an assistant who at the start had had no experience whatever in photography. This assistant was shown how to handle the strips of film properly and was told that the water should be cool, the developer always of a certain strength and the development carried on for a given time. When the films are thoroughly fixed the author takes them in hand to make the minute alter-

ations with the reducer and intensifier, which work, as will be shown, is considered not so much a corrector of errors as a recognized part of the real work of placing the negative when finished at the desired point of opacity and contrast.

The folly of expending mental effort on methods of exact development is seen by the accompanying illustration in which three films were given like normal exposures (Plate XII). One of them was then developed for four minutes, another for eight minutes, the normal time for the developer used, and the other for twenty-four minutes. Otherwise than this variation in time the conditions were uniform throughout for all three negatives. When the negatives were fixed the over-developed one was reduced to the desired opacity, or as near as possible to that of the normally developed one, and the under-developed one was intensified to the same opacity. Each of these processes required but a few minutes to perform. The three illustrations by their similarity, prove that it is practically indifferent how long correctly exposed emulsions remain in the developing solution *so long as they are afterwards brought to their correct density by reduction or intensification.* This of course is quite consistent with the "law of constant density ratios" discussed before (chapter VIII). Since both developers and emulsions vary as to the speed with which

they develop it is seen to be useless to complicate the worker with any special system of developing.

As has been insisted, the relation of the gradation steps is fixed in the exposure and the practical point to be attained in development is simply to approach an opacity and contrast *suitable for the printing medium to be used and the tone gradation desired.* This opacity may sometimes much better be secured in the light by the use of a reducer or an intensifier than be sought for over-carefully in the dark room in the developing solution, as plate XII proves.

It should be realized that the work of developing an emulsion of which the inertia has been overcome in the exposure a known number of times is entirely different in character from developing one of which the exposure has been estimated and which must be watched for signs of under- or over-normal exposure. This certainty in development, made possible by known and predetermined exposure, when fully realized will justify the opinion of the author that development is the one branch of photographic labor which is practically mechanical, the result simply proving that previous work has been well comprehended and executed.

Whatever method of development be employed care should be taken to use a solution of normal strength at a temperature close to 65° F. or 18° C. The time of development should be gauged so

as to secure as near as possible the opacity desired in the negative or negatives being developed, in view of the contrast of the paper or other medium in which the picture is to be printed and also of the tone effect desired. This is simply for the convenience of avoiding as much as possible the work of after treatment. On using any formula as given, should the time required to develop a negative be less than three or four minutes it is advisable to increase the quantity of water in the formula until a development of about five to six minutes gives the correct or approximate density. The reason for this is to give the emulsion time enough to become thoroughly impregnated with the developing agent, and thus avoid lack of uniformity in the result. The developing solution should be used but once.

With correct exposures and the quick method of after treatment to be given it is evident that a time method of development, whether in a tray with the machine or in a tank, is ideal. It should be unnecessary to add that great cleanliness should be observed in all work. It is taken for granted that the reader is already acquainted with the ordinary process of developing and finishing a negative and as published formulas are so abundant it is not deemed necessary to include more than a mere outline of this practice.

Fixing. — When development is finished the

negatives should be well rinsed in clean water and passed to the hyposulphite of soda bath which preferably should be made fresh for each batch of negatives. For the fresh bath the author recommends one part of powdered hypo in two parts of water, estimated according to the volume of each rather than the weight. The powdered hypo is recommended only to save time and bother as it dissolves almost immediately by slight stirring. Once the negatives are well saturated by this bath the usual light no longer affects them. They should remain in the fixing bath twice as long as is required to take away the creamy color from the back. Some agitation in this bath is advisable and when several films are treated together they must be moved constantly during the entire time even though they appear to be fixed, for the future permanency of the negatives depends upon thorough fixing, especially when they are to be treated afterwards by reduction or intensification. The author has at times used the acid fixing bath according to the standard formula and followed it by reduction and intensification (after 2 or 3 changes of water) without any stains or other evil results. The bath has never been used however more than three times without renewing. The importance of using a fresh hypo bath cannot be overestimated.

When fixation is complete is the time for careful inspection in appropriate light to determine

whether any of the negatives should be reduced or intensified. In actual practice the author frequently has from 10 to 20 exposures without one needing any after treatment. Should any need reducing, however, either locally or generally, the work is taken up when the negatives have been removed from the hypo to the first water. Should none require either reduction or intensification, however, they should be given 8 to 10 changes of water, or better still if convenient, at least half an hour in running water. When washed they are placed to dry free from dust. Should any require after treatment, however, all should be left in the first water after fixing and the work should be proceeded with as explained in the section on reduction which follows.

REDUCTION AND INTENSIFICATION

These operations have heretofore usually been performed on negatives which have been previously dried and perhaps printed from. This practice is wrong. *Negatives should never be dried without first being brought to the desired contrast.* In the present method the work of reduction or intensification or both if necessary are considered as logical and legitimate steps in bringing the negative to the above-mentioned desired state. Although the majority of negatives should need no after treatment when de-

veloped and fixed, the act of development proper should be considered in practice to be but the creation of a chemical base upon which by visible processes done in the light the perfect negative may be built. The mistake has been to consider the work of development alone as the complete or final act in securing opacity or in negative making. Plate XII (p. 121) illustrates conclusively how little depends on the exact condition of the negative after development alone so long as the after processes are recognized and used in the normal work of making the negative.

To prepare for this work a stand should be made in which are involved the principles shown in profile in figure 10 on the opposite page.

The top of the arrangement, a, is clear glass on which the negative is placed for treatment. The line c indicates the position for a thin board or cardboard on which may be laid a clean white paper. The negative is examined and treated by looking through a to the lighted surface c. The line b indicates the position of a shield for the eyes and for keeping the direct light from striking the negative and should be of tin or some other non-inflammable substance since the chimney of the lamp will be very near it. The glass should be somewhat larger than the size of the negatives to be treated and its edges should be well ground off in order not to injure the film when a whole roll is laid across it in order to treat the various

negatives in it. This grinding may be done sufficiently well with the edge of any other piece of glass. The glass may rest on a simple frame made by nailing four small pieces of board together and attaching four legs so as to raise to a height of about 8 or 10 inches. The glass should be level so that the solutions will

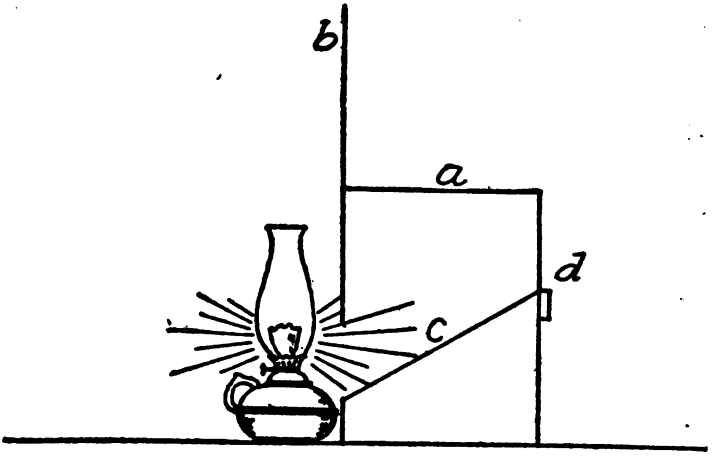


Figure 10

not run on being applied to the negative. Use a low lamp or any other convenient light and nail the tin, b, so that its lower edge will come even in height with the top of the lamp flame or other light. By nailing a stick across from leg to leg at d, the carrier for the white paper may be laid across it, the inner end resting on the lamp globe or in a like position for any other light, as seen in the figure.

Some such device is necessary in order that

the two hands be left free for the work. It is impossible to see the quality of a negative by looking through it toward a flame; hence the necessity of using the reflecting surface c.

REDUCTION

The negatives being thoroughly fixed may be lifted from the fixing bath, rinsed once and examined on the above device to see if there are any which require reducing locally or entirely. If a negative be found too dense throughout it should be dipped once more in water and placed in the following well known Farmer's reducer:

Ferricyanide of potassium (red prussiate of potash)	15 grains
Hyposulphite of soda	90 "
Water	2 to 8 ounces

Or without weighing:

Ferricyanide	about the volume of two peas
Hypo	about six times that volume, and
Water	1/8 to 1/2 of a glass

Weighing is unnecessary and the less water the quicker the solution works and the oftener the plate should be examined while in the bath. When it reaches the desired opacity dip in water and then pass to another clean water where it may rest until all are reduced which require it.

It is frequently desired to reduce some particular area of a negative without altering the rest of it. This is termed "local" reduction. Such an area may be that of white drapery

which, in the time required to print the face correctly, would not be sufficiently detailed by the penetration of the light through that part. It might be the sky with clouds in an exterior or the small areas of white objects, as gloves or flowers, or the reflections from metal or other reflecting surfaces. Or it might be that the density of a road or path or the shadows of drapery folds require to be lowered, or perhaps it is some part of a background or drapery in a portrait.

Too great reduction of any local part makes that part "out of tone," unless the part be where deep shadows might naturally have been in the arrangement of a subject as for example the lower part of the clothing in a bust portrait, the detail and somewhat high tone of which it is frequently desired to eliminate in order to secure a so-called broad effect. The out of tone effect above mentioned is easily detected as it represents the part as darker than it could have been, in relation to the objects about it, under the light conditions which prevailed and which should be evident from the appearance of any picture. A little practice will suffice to teach anyone how far he may go in this work of local reduction.

In reducing locally it is annoying to find after the reducer has been mixed a minute or two, that its vigor is gone and a different "technique" is advised to avoid this trouble. Place in separate

small graduates the two chemicals mentioned in the formula above (without weighing). Then add enough water to the hypo to just nicely dissolve it. Then fill the other graduate up to the same level and dissolve. Then to use, squeeze out with the finger two or three of the small, quill, camel's hair brushes of each solution into another very small dish and use from that. As soon as its action slows, rinse the dish and the brush and combine another small quantity as needed. In this manner one can work with a full strength solution until the two solutions are used up.

For reducing small areas use very little water in mixing the above solutions in order to make it work very fast and see also that the excess of water is removed from the area to be treated before the reducer is applied. This may be done by passing a piece of slightly moistened absorbent cotton over it. A soft brush should be chosen appropriate to the size of the area to be treated and the excess of solution should be pressed from it in order that on touching it to that area the solution will not run to the adjacent areas and reduce in a spot or path (as this solution works almost instantaneously) where it is not desired. The speed with which the solution works when very little water is used makes it possible even to draw lines in the negative if desired but the necessity for care and good taste increases with the liberties which are taken in the work. One should have in the left hand a tuft of wet absorb-

ent cotton ready to apply to the part treated, as the delay of a single second could easily spoil a negative completely. A short application of the reducer followed by that of the wet cotton allows the work to be done tentatively, making it much easier to watch and control. As has been mentioned in the chapter on developing, the best fixing bath is a fresh one made of hypo and water only, as with thorough fixing and cleanliness no fear need be had of stains during or following reduction and intensification.

Should a number of negatives have been developed at one time it is best to leave the whole batch in the first wash water until those requiring to be reduced have all been treated. All may then be given four changes of water to prepare for intensification. If it should be necessary, even those which have been once reduced may be now intensified either locally or generally. Intensification may now proceed.

INTENSIFICATION

Intensifier:

12 grams	bichloride of mercury	dissolved in	400	c.c.	of	water		
15 "	iodide of potassium	"	"	40	"	"	"	
24 "	hyposulphite of soda	"	"	60	"	"	"	

Or:

1/2 ounce	bichloride of mercury	dissolved in	20	ounces	of	water		
5 drachms	iodide of potassium	"	"	2	"	"	"	
1 ounce	hyposulphite of soda	"	"	3	"	"	"	

Dissolve separately and combine the first and second and then add the third. Slightly warming the water for the mercury saves time in dissolving it. Keep the solution in a wide-mouthed, glass stoppered bottle. Great care should be exercised in mixing and storing this bath as the mercury is excessively poisonous. Never put the bare fingers in the solution but use rubber tips or gloves.

In practice the author uses the following method for dissolving the chemicals as in this manner a still stronger solution is obtained which acts almost instantaneously in local work: Place the dry mercury in a mortar and add to it a small quantity of water by estimation, say an ounce or about 30 c.c. or less. About 50 turns of the pestle saturates the water completely with the mercury when it is allowed to settle for a few seconds and the clear solution decanted off into the bottle. Repeat this operation as many times as is necessary to carry off all the mercury. Then rinse the mortar and dissolve the potassium all at once in a small quantity of water and pour it into the bottle with the mercury solution. On dissolving and adding the hypo in a similar manner the bath will become clear, with slight shaking, and is then ready to use. Do not use warm water for this method as the bath would be too strong to use successfully. For local work pour out only the necessary amount of solution and after using it pour

into a separate bottle and save for general work. This solution keeps well and for general intensification it can be used repeatedly until it begins to work too slowly when it should be thrown away. It may of course be weakened with water for general work if it is desired to slow its action. In this case, however, a little of the full strength solution should be saved in a separate bottle for use in local work.

Should a negative be unintentionally over-intensified it may be again reduced by first washing it well in several changes of water and then placing in a strong, fresh solution of hypo and water. This work may also be done locally by applying the hypo solution with the regular reducing brushes or with absorbent cotton in the usual way. In fact the cotton may be used instead of brushes for all this work but rubber finger tips or gloves should then be worn as has been stated. Or the tuft of cotton may be twirled on the end of a stick, as the spindle from a film roll with the metal ends removed. Three soft brushes of different sizes, one set for reducing and another set for intensifying are, however, much preferable. The smallest should be a rather large ordinary "spotting" brush, the medium one an ordinary round quill handled camel's hair brush, and the largest should be a half inch or a one inch, rubber bound camel's hair brush.

Local intensification should be done on the

stand with the strong solution, but a tray with weaker solution should be used for treating the negative throughout. The precautions in technique as mentioned in the section on reduction, such as refer to the excess of solution when treating small areas, etc., apply the same to intensification.

As the negatives are intensified they are returned to the bath with the others and when all are finished they should be washed thoroughly and placed to dry. It is advisable to go over each negative with absorbent cotton just before placing to dry to take off any sediment which may be clinging to it. In the case of films the author has found in practice that ten changes of water given with not less than two minutes moving in each, is sufficient to wash them thoroughly.

The importance of any method of working cannot be judged logically until one has really made it a part of himself and when this method of treatment, which is performed in bright light and under conditions which give absolute freedom to the judgment, shall be recognized and used as a legitimate part of the process one takes on a feeling of freedom and power in the making of his negatives which cannot be experienced in any other way.

Negatives which are of historical importance should be duplicated or should have positives made from them by contact on plates or film,

from which any number of negatives may later be made, also by contact. For reasons of permanency such positives and negatives should be brought to the desired opacity in the developer, or should be over-developed and then reduced, as the permanency of intensified emulsions is always a matter of doubt.

CHAPTER X

PRACTICE

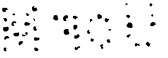
THE ACTINICITY OF THE SUBJECT

IN photographing any subject having sufficient area of uniform intensity at its brightest part to admit of measurement with the f / 1 meter the intensity of such part may be measured by the standard method. The expression "the actinicity of the subject" means in practice the actinicity of the maximum or "objective" point in the subject and this is the point always measured in actual practice. Less time is required however to take the first appearance time of the light incident upon a subject, and since its intensity in actinos may be found in this manner as well as by the standard method, as has already been explained in chapter 4, problem 3, this method may be used generally in practice if desired.

A PRACTICAL ANALYSIS OF SUBJECTS

It has undoubtedly occurred to many readers that the classification of white and black and the different colors as to their inherent actinicities is a refinement seldom necessary in practice. The purpose has been to establish in the mind

Plate XIII — MOTHER'S BOY



of the reader a true conception of actinicity as a quantitative value pertaining directly to all surfaces. In practice, however, should a white and black cloth be stretched flat and be photographed separately with a normal exposure on the basis of their respective actinicities, it would probably be somewhat difficult to distinguish the photographs from each other, supposing that the cloths be of like texture. As to tone, such a result could not be spoken of as a "natural" rendering since by varying the depth of printing, a light or a dark print could be made at will from either negative. On the contrary, should the two cloths be photographed side by side in the same picture, the exposure being given on the basis of the actinicity of the white one, then, should the emulsion have considerable latitude, each cloth would be represented in its proper position as to tone.

This brings the reader back to the consideration of the "dominant," "objective," or brightest part of a subject and its importance in the actinic analysis of subjects and emphasizes anew the importance of knowing the actinic gradation of a subject throughout and the agreement of the latitude of the emulsion with that gradation. For example had the plate used in the above case had a latitude of only 1 to 8, it is clear that the white and the black cloth could not have been properly photographed in the same picture by purely normal exposures on the basis of the

white, since their actinic contrast is at least 1 to 16 and with such an exposure the intensity of the black cloth could not have overcome the inertia of the emulsion.

Should one be photographing a somewhat open view of the mid-distance class, and the sky be considered as the maximum point and its intensity be taken as the basis of exposure, a white and a black horse in the mid-distance would each assume its proper place in the tone gradations of the picture, always providing of course that the work of developing, etc., be performed properly. On the other hand should it be desired to obtain a perfect photograph of each of the horses separately and of good size in the picture, the black one should actually have about four times the exposure required for the white one, although the actinicity of the former is only about $\frac{1}{16}$ that of the latter. It is obvious that the image of a black object should overcome the inertia fewer times than that of a white one since its tone in any picture should naturally be darker than that of a white object.

In studying nature from the view point of practical photography it is convenient, as has already been explained, to divide all subjects into two general classes: those whose actinic gradations are created by nature and which must be photographed as found or be modified by the selection of view point or lighting, as

by choosing a time when the sunlight is modified by a cloud or when it shines upon the subject from a desired direction. The other class consists of those subjects which by their nature are almost wholly in the worker's hands and whose gradations therefore must, or should be, wholly arranged by him (p. 87, 102, 141).

Out door subjects are naturally of the first class since the sun and sky cast their light over nature in their own way and we can only select as already explained, the conditions of view point and the time of day when the lighting pleases us most.

As helps in composition or pictorial construction it is necessary to distinguish between subjects of the foreground, mid-distance and distance class. Subjects of the distance class are usually spoken of as bird's eye views and their characteristic is that they have no near objects whatever in them and little else besides a horizontal or rolling expanse of grass or earth, or what would be in view when looking down from a somewhat high point as in overlooking a valley. A mid-distance view is one which has some objects in it but of such size that their images would not fill more than about one fifth of the dimension of the plate in either direction on being photographed.

Foreground subjects are of course those with objects so near the point of view as to occupy a good part of the field of vision or to occupy a

good share of the dimensions of the plate on being photographed. Even in mid-distance subjects the surfaces of objects in the view are both visibly and actinically equalized, to an extent, by the atmosphere lying between them and the eye or lens; the pure white surfaces being somewhat lessened in intensity from the fact that the intrinsic actinicity of the atmosphere which intervenes is less than that of a pure white surface, the former acting therefore as a screen between the objects and the point of view. On the contrary this atmospheric screen or layer raises the value of all shaded areas as well as of fully lighted areas whose color is of less intrinsic actinicity than the blue of the atmosphere itself.

Considered actinically, mid-distance and bird's eye views may usually be classed the same, and may be thought of as "open" views on which the full light of the sky with or without that of the sun, shines down uniformly over the whole expanse. Foreground subjects, however, being practically free from the effect of intervening atmosphere, are more variable in their intensities and the principal objects in them must be thought of more in accordance with their own light or dark color or their particular inherent actinicities. This is made clear in the example on page 138, of the white and the black horse when photographed large on the plate or as foreground subjects.

Portraiture will at once be recognized as providing the principal subjects of the second class or those in which the lighting should be the result of the taste and knowledge of the worker. Still life subjects and nearly all subjects situated near the camera are also of this class as the background for such, as well as the lighting, is usually selected and their gradation thereby at least partially arranged or chosen. (See pp. 87, 102, 139.) The painter takes from his tubes of paint that which, more or less modified, becomes the light, the dark and the intermediate tones of his picture while the photographic worker must obtain this gradation of tones by means of the opacity gradations in a negative which in their turn are secured directly from the actinic gradations of the subject. The photographer therefore must think *tones* in *actinic intensities* and should he compose a portrait subject for example, his high lights may be secured directly from the sky and the half tones may come straight from a sheet or towel held in the right place to impart the desired actinic balance to the face. The photographer should be able to select and modify actinicity as freely as a molder handles his clay.

With the average emulsion the actinicity on the shady side of a face for example, which will produce an agreeable half tone in the picture is about one fourth that of the brightest part of the face, which is usually one side of the fore-

head and which is to produce the high light of the picture. It is very evident then as has already been explained, that the photographic worker must know actinism as his all important working tool or medium. In order then that one may make beautiful and artistic pictures with the photographic process it is evident that he must be able to conceive pictures which have beautiful and artistic qualities and then be able to build or compose his subjects so that its whole composition and lastly its actinic gradations, will produce, through the medium of the negative, the composition and tone gradation previously conceived.

The master of actinic construction must be able to secure in a portrait any desired effect of light and shade and tone gradation out under the open sky, with a few screens in the hands of assistants to modify the light and until this standard of freedom and dexterity is reached no one can be said to have attained to a high degree of ability.

Interiors of rooms may be classified as light, medium and dark in color with an additional special class, "dark machinery," since the broken and irregular form of such a subject tends to shade some of the parts abnormally. Portrait subjects are classed as of light, average and dark complexion; the average being that of the average man. The complexion of the average woman and child may be classed

as light since the greater smoothness of the face as well as the lighter complexion permits of relatively less exposure. This classification will be found correct in practice.

In portraiture the unit actinicity of the brightest part of the head, as the forehead or cheek, may best be measured with the $f/1$ meter, and the regular exposure rule followed. However it is well to include this subject also in the method for measuring the incident light.

The numbers in the following table may be considered as denoting either the p.o.p. time of the light with which the subject will have one actino of intensity, or perhaps simpler, the intensity of the subject in actinos when the p.o.p. time is one second. The number pertaining to any subject, divided by the p.o.p. time of the strongest light which shines upon it, gives the actinicity in actinos.

CLASSIFICATION OF SUBJECTS

Exteriors:

Clouds with sun directly beyond them as for obtaining the so-called moonlight effects	2M
Average clouds in sunlight not in above position	512
New snow	256
Bird's eye, mid-distance, marine and old snow views	128
White subjects, foreground and otherwise	128
Average exterior	64
Dark colored foreground subject as green trees, etc.	32

Portraits:

Light complexion	64
Average complexion (that of the average man)	32
Dark complexion	16

Room Interiors:

White walls	128
Average walls	64
Dark walls	32
Dark machinery	16

In order to make still clearer, if possible, the meaning and purpose of the foregoing table suppose that in a certain case on measuring the light its p.o.p. time is found to be 1 second; the actinicity of any subject then would be exactly as given in the table. This in fact is exactly what the table is, as has already been stated, viz., *the actinicity of each particular subject when the p.o.p. time of light is 1 second.* In a certain case should the p.o.p. time measure $\frac{1}{4}$ second then it is evident that the light is four times as strong as the conditions provided for in the table and the intensity of any subject must therefore be four times that mentioned in the table. Or according to the rule given, the actinicity given in the table for any subject, divided by the p.o.p. time of the light, gives the actinicity of that subject.

Note that the average exterior subject, when the p.o.p. time is 1 second, has an intensity of 64 actinos and that, aside from clouds and new snow, no subject has more than double, and only very dark subjects less than half that intensity in the same strength of light.

As a concrete example of the method throughout, suppose that it is desired to photograph

an ordinary landscape whose actinicity with a 1 second p.o.p. time (the conditions of the table) is 64 actinos. Now on measuring the light the p.o.p. time is found to be 8 seconds, the sun being at the horizon. By the rule: $64 \div 8 = 8$, the actinos of intensity of the subject. Or by analysis: A p.o.p. time of 8 seconds indicates a light strength only $\frac{1}{8}$ as great as would be indicated by that of 1 second, the condition provided for in the table, and the intensity of the subject will of course be only $\frac{1}{8}$ of the table intensity of 64 actinos or 8 actinos. Now suppose that it is desired to photograph this scene on a plate which has a speed of 4 minutes. Now since 4 minutes, the speed time of the plate, is the exposure with diaphragm number one when the intensity of the subject is 1 actino, the exposure with the same diaphragm when the subject has 8 actinos of intensity will be $\frac{1}{8}$ of 4 minutes or $\frac{1}{2}$ minute, or as already explained, 32 seconds. And if the exposure is 32 seconds with unit scale diaphragm number 1, and it is desired to expose with number 64 the exposure will be $\frac{1}{64}$ of 32 seconds or $\frac{1}{2}$ second. This, on reading, may seem somewhat complicated or extended but the fact is that the only operations are to divide, in this case, 4 minutes by 8 and the result, 32 seconds, by 64. It is evident that two such simple mental divisions cannot be a lengthy proceeding.

Each worker may alter the factors given in

the preceding table in order to ascertain by trial the values which produce results pleasing to his own taste. In fact the consideration of all values quantitatively should make one absolutely free to ascertain for himself the speed of any plate or film used as well as those factors in practice which give pleasing results according to his own ideals. If one does not quickly reach this stage of freedom in his experience, it is certain that he has not fully grasped the fundamentals of the system. It is strongly recommended that the student practice all the experiments outlined, especially those referring to the speeding of emulsions, measuring the light, etc., and also that the unit scale of diaphragms be placed on his lens or shutter so that all work done by the light and the lens upon the sensitive emulsion may be accounted for by the ordinary processes of reasoning and by means of simple units as has so often been explained and illustrated. A comprehension of the convergent theory of light measurement as applied in the $f/1$ meter and in lens diaphragms and also in all light calculations, is essential in establishing perfect freedom in the analysis of all light conditions.

The p.o.p. time method of measuring incident light is already somewhat known, being the same as taught in the author's book "Home Portraiture," where it is mentioned as the "Solio time" of the light, and in his later book — "Steadman's

Complete Exposure Method and Home Portrait Helps" where it is spoken of as the "tint time," the "p.o.p. time," or "first appearance time" of the light as in the present work. This measurement is also used as the light factor in working the author's "Aaba Exposure Scale."

ANOTHER PRACTICAL METHOD OF TAKING THE UNIT ACTINICITY OF EXTERIOR SUBJECTS

Referring to page 48 it will be seen that the slow tinting mediums of the solio class, when exposed in the *f* / 1 meter to the maximum light of the sky shows a tint time of *one* second and that this time indicates a 512 unit actinicity for the light source. Now while it is not at all times convenient to take a unit measurement of the brightest lighted area of a subject in exteriors by reason of its character, its distance from one, etc., it would be very simple ordinarily to make a unit measurement of the sky above it if it is clear and judge the value of the subject by comparison.

Should the sun be shining upon the subject its actinicity, relative to that of the sky, would be greater than if direct sunlight were absent. With white objects in the view it might be necessary, to judge the actinicity of the subject as double that of the sky, especially in the case of mid-distance subjects.

A view with all green trees and grass could be judged as having only $\frac{1}{16}$ the actinicity of the sky and other subjects $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ or equal actinicity,

depending on their color and whether they be foreground, mid-distance or bird's eye subjects.

STILL ANOTHER OPTIONAL METHOD

The foreground and other subjects referred to in the preceeding paragraphs are of the nature of "open views" or those whose planes recede into the mid distance and beyond. There is another distinct class of foreground subjects which it is necessary to notice since their actinicity can not be judged from a measurement of the sky and another method must be provided. These might be described as "closed in" or purely foreground subjects since they are limited as to distance by their own selected or arranged background which rises immediately behind them. In this class are the studio portraits of the professional photographer and all portraits whether in or out of door, still life, commercial subjects, as furniture, implements, etc., and in fact all subjects which are photographed large on the plate and which are closed in by their special background as has been described.

Perhaps most such subjects are photographed indoor entirely away from any overhead sky but even in the case of exterior subjects, as for example, portraits with a shaded grove or a wall as a back ground, it is frequent that there would be no rational basis for comparing the actinicity of the sky with that of the subject. This is true when the sky area is confined to a limited opening, as between trees, in order to "concentrate"

the light as is necessary to secure an effect of light and shade on the subject.

Now in portraiture the cheek or forehead can be measured with the *f*/1 meter in the usual manner but when a subject has in its brightest parts no area large enough to be so measured, as would be the case for example with a still life subject of fruit or flowers, then a white card may be held near the subject, so as to catch the maximum light and its own actinicity measured. From this measurement the actinicity of the subject can be judged according to its predominating, or most actinic color. For this purpose the back of an ordinary white business card may be used but it is preferable to cover a cardboard with white cotton or linen cloth as there is less direct reflection in such a surface. This should be made of a size to go conveniently in a coat pocket.

For the relative "inherent actinicity" of the different colors as compared to white see the table on page 64.

This method is not only simple in practice but is excellent for training the eye to see the characteristic differences between subjects; the bird's eye view with its horizontal planes — the mid-distance view in which these planes are dotted with lower actinicities of small expanse and the different classes of foreground subjects with their perpendicular planes, varied colors and varying contrast and the absence of all haze which characterizes distance.

THE CHARACTER OF SUNLIGHT WITH CLEAR SKY

When the sky is clear the actinicity of sunlight depends almost wholly on the sun's position with regard to the horizon. Many exposure tables give the exposures for certain latitudes and the different months and hours of the day, but the combination of these three conditions is solely for the purpose of conforming to known heights of the sun above the horizon. As this last may be seen at a glance it seems unnecessary to refer to the non-essentials of hour, month and latitude. The sun must always be at the zenith from some point or other on the earth's surface and if from this point as a center a circle be imagined to be drawn on the earth say 60° from it then from every point on that circle the sun would rest at 30° from the horizon and the sun's light to reach any point on that circle must pass through the same distance of the earth's atmosphere. The same would of course be true of any other distance from that point at which the sun is at the zenith. The problem is really very simple and consists in knowing the maximum intensity of the sunlight when it shines through the earth's layer of atmosphere at right angles to it and then to know how much that intensity is reduced as the sun shines from directions approaching the horizon. It is a matter of fact, as has already been ex-

plained and used in this book, that when the sun is at the zenith a least visible tint is made by its light assisted by that of the sky on gelatin printing out paper in $\frac{1}{8}$ of a second.

These facts suggest that in clear weather the sky may conveniently be divided into intensity zones, the intensity for each zone being the p.o.p. time when the sun is in that zone. The position of the sun by this method is always found by making a comparison between it and that part of the horizon immediately beneath it. When the lower rim of the sun rests on the horizon the p.o.p. time is usually 8 seconds and the light is therefore only $\frac{1}{64}$ as intense as it is with the sun at the zenith. The diameter of the sun is a little more than half a degree and if its lower edge is less than one of the sun's diameters above the horizon the sun may be said to be in the *one degree* zone. It is to be understood that the 16 degree zone includes the belt of sky from that height down half way to the horizon or to 8 degrees; the 8 degree zone — from 8 to 4 degrees, etc. The zone of which the zenith is the center, that from 40° upward, should be known as the "maximum" zone. These zones may also be spoken of simply by their p.o.p. time, the maximum zone being that of $\frac{1}{8}$ second. The table of zones and the p.o.p. time of each follows.

Intensity zones in which the sun rests	The p.o.p. time of sunlight in these zones
1° zone — 1° and lower	8 seconds
2° " — 1° to 2°	4 "
4° " — 2° to 4°	2 "
8° " — 4° to 8°	1 "
16° " — 8° to 16°	1/2 "
40° " — 16° to 40°	1/4 "
Maximum " — 40° to 90°	1/8 "

The weaker values, when the sun is near the horizon, are extremely variable by reason of temporary weather conditions, and the afternoon light is also frequently slower than the morning light. It must therefore be understood that the above table is only for perfectly clear weather conditions. Figure 11 illustrates these zones. The sun is shown in the maximum or $\frac{1}{8}$ second zone. Figure 11.

Wherever in the sky the sun may be, the p.o.p. time of its light may be known at a glance by memorizing the following two methods of observation: The former to be used when the sun is 8° or less from the horizon and the latter when the sun is above 8°. When the sun is low, this method, obviously, is effective only where the horizon is of the same altitude as the observer, as on the sea or on level ground. Among hills and mountains the light should be measured by one of the methods given.

The zone in which the sun rests when rather low may be seen by the number of its diameters it is above the horizon. To observe the sun one may look through a piece of smoked glass or a

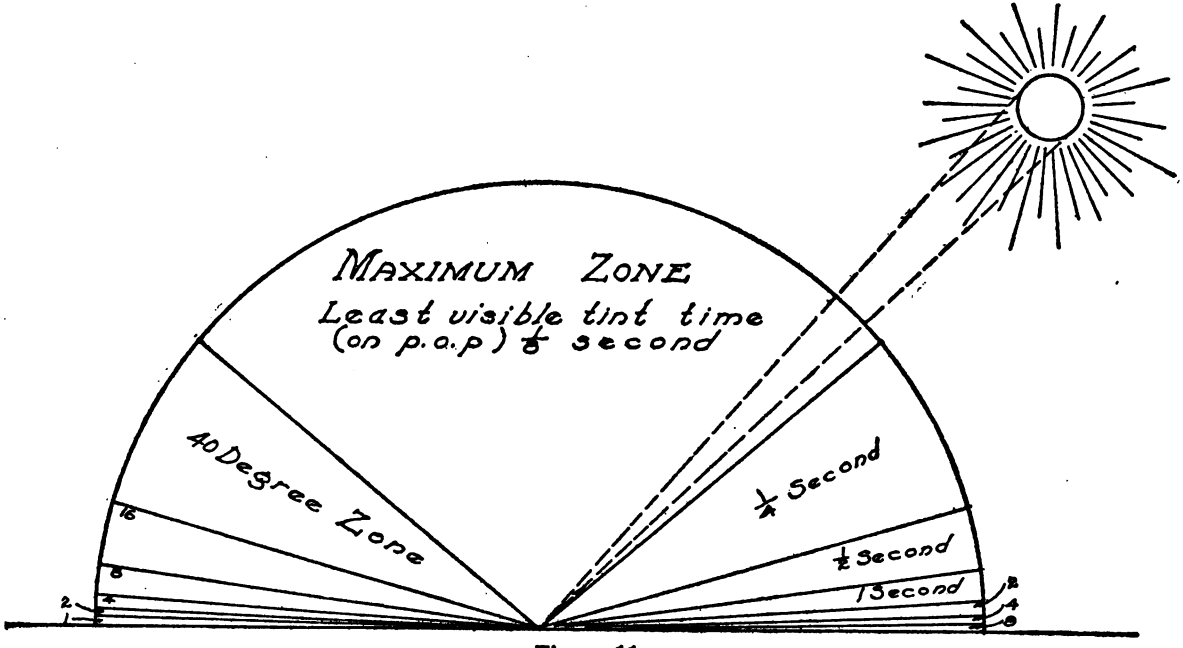

MAXIMUM ZONE
Least visible tint time
(on p.o.p) ¼ second
40 Degree Zone
16
8
4
2
1
¼ Second
½ Second
1 Second
2
4
8

Figure 11

piece of old negative, which need not be more than a half inch square and which may be cut from a spot which on trial proves the correct density to allow the sun to be looked at conveniently through it.

The sun's diameters above the horizon	The p.o.p. time of the light
1 or less	8 seconds
1 to 2	4 "
2 to 5	2 "
5 to 12	1 "

From this point upward the zone may best be ascertained by standing on level ground and noting the length of one's shadow as compared to his height. This ratio may of course be found by comparing the length of any shadow on a horizontal plane, with the height of the object casting that shadow. For example on a card, held horizontally, may be placed the back of a knife blade, the edge extending upward, and if the sun be shining across the blade at right angles to it the relation of the shadow length to the height of the blade may easily be observed. These ratios are now given which indicate the p.o.p. times of one second and less.

Length of shadow compared to height of object casting it	p.o.p. time of the light
7 to 14 times	1 second
4 to 7 "	1/2 "
1.5 to 4 "	1/4 "
less than 1.5 times	1/8 "

Should one be acquainted, however, with the disappearing scale of tints (p. 41) even the

brightest sunlight may easily be measured on p.o.p. with a "contact opening" and although it should never be necessary to do so, it is well enough to know how such a measurement may be made. When the day is clear and the sun in the maximum zone, 40 or more degrees from the horizon, a quarter second exposure of a slow tinting medium will give a depth of tint which immediately should be recognized as the second visible tint of the disappearing scale. Without actually making an eighth second exposure, which is too fast to give with the unaided hand, it is evident then that such an exposure would give the least visible tint and that the p.o.p. time is really $\frac{1}{8}$ second. Of course, when the sun is nearer the horizon the light can easily be measured and it is recommended to do so.

To be able to estimate the intensity of sunlight at a glance, however, through a knowledge of the intensity zones, is a useful and desirable accomplishment since it saves one the trouble of measuring bright sunlight and also impresses the worker with the stable character of that kind of light. On dropping below the horizon the light becomes weaker more or less rapidly according to the angle at which the sun has passed it. In the tropics after sunset night approaches very quickly indeed but in the latitude of Norway, for example, when the season is such that the sun just drops below the horizon at midnight the p.o.p. time of the light in

clear weather may be 16 or 32 seconds at that hour, since midnight in such a latitude may compare in brightness with early twilight in the temperate zones.

Under all such conditions of weak light it has already been explained that in order to save time a faster tinting medium may be used and the time as found multiplied by the factor of the slow p.o.p. as compared to it in order to secure the time as though taken with the p.o.p. It is frequently convenient to use one of the so-called "gas light" papers, such as Argo, Cyco, Velox, etc., as these papers on the average require only about $\frac{1}{4}$ the time to tint as is required by the gelatin papers. By taking the p.o.p. time of the light with both gelatin paper and any convenient gas light paper at two or three steps from a window it may easily be seen how many times faster the latter is than the former and under weak light conditions the time found with the faster paper, multiplied by this number or factor will give the p.o.p. time as though measured with the gelatin paper. (See pp. 41, 47.)

AN EXPOSURE RECOMPENSE

In photographing near objects the lens rests further from the plate or film than it does when focused on a distant object. For example, should a lens of 16 cm. focus be 2 cm. in diameter its convergence will be $f/8$ when focused on a distant object; but in drawing out the lens

in order to focus on a near object, should it rest 2 cm. further from the plate than when focused for a distant object the actual focal distance is now 18 cm. and not 16 and its convergence is $f/9$ instead of $f/8$ as before. And should it be drawn out until it rested 16 cm. further from the plate than it does when at the long distance point it would be 32 cm. from the plate and its convergence would be only $f/16$ instead of $f/8$. Since the latter is a convergence of 64 cone units and the former of only 16 it is seen that *solely on account of the position of the lens* the exposure should be increased four times, should the lens rest in the last position mentioned. In practice it is best to ascertain the exposure with any desired diaphragm by the usual method and as the last step observe the position of the lens and the increase of exposure made necessary by it. The following method enables this recompense to be made very easily.

All film cameras have a focusing scale on which is seen a 100 foot or a 30 meter mark which indicates the position of the lens when focused on distant objects. On cameras having no scale this mark should be made. This may be done by focusing with the open lens on any distant object and then making a mark on the solid part of the camera where the face of the sliding part which carries the lens rests. Now multiply the focal length of the lens successively by 0.19,

0.41, 0.67 and by 1 and at these measured distances out from the long distance mark make other marks on the camera bed and number them respectively 1.5, 2, 3 and 4.

Then on photographing any near object note the mark nearest which the lens rests and multiply the exposure as found under any conditions by the factor at that mark. For example should it be found under certain conditions of subject, light and diaphragm that an exposure of 2 seconds was required and it is seen that the lens rests near the point marked 2, then the exposure should be twice 2 or 4 seconds. Should the lens rest near the outer mark having the factor 4 then this exposure should be 4 times 2, or 8 seconds.

THE SPEED OF PLATES AND FILMS

A speed list, if incorporated in this book, would soon be out of date, since new plates and films are continually appearing on the market.

In chapter 5 it has been made clear that each exposure in practice is really a test and proof of the speed of the plate used. In this method the speed of a plate *is* the exposure which it requires with unit stop when the surface photographed is of unit actinicity. For these reasons then it is practical for any worker to test the speed of the plate or film which he is using in his daily practice and it will suffice here to give a general idea of the speeds of different types of plates so that an

approximation may be arrived at for the first trials. The extra slow contrast or process plates may be represented by the Cramer "Contrast" and the Lumière Red Label which have speeds of 32 and 128 minutes respectively.

The popular fast plates of both Europe and America are very close to 4 minutes, or better, 256 seconds in speed. That is to say, given a subject of unit actinicity and using in the lens the unit stop (or stop *f* / 64 or U. S. 256 of the scales now in use), that time would be required to effect a normal exposure. None of these plates would fail to give a good negative on this basis, so far as the time of exposure is concerned. But after a single trial with unit measurement of subject as has been made clear, should the plate or film seem to be rather over-exposed then it would naturally be understood that 256 seconds had over-exposed the plate and half that time or 128 seconds would be considered the correct speed, this to be altered at will by the worker to suit his own taste in the matter. If on the other hand the plate seemed under-timed then it would be evident that it should have been exposed twice as long and that its speed is 512 instead of 256 seconds.

The ultra fast plates on the market may be tried at first on the basis of a 128 second speed. The reader should remember that the speed time of emulsions as explained in this method is based on a chemical effect that will develop in a normal developer and in a normal time (or at least, in the case

of the ultra fast plates, without undue forcing) into a normal negative. For purely practical reasons these ultra fast plates may be taken as having double or four times their normal speed (one half or one quarter their normal speed time) since they are rarely used except under extreme conditions where a certain amount of under-exposure must be allowed in order to stop motion in moving subjects which are sometimes in the shade, as under the most exacting conditions of press photography.

I have shown how to arrive at the speed-time of a plate or film on the basis of correct exposure to a subject having unit actinicity, with the unit stop ($f/64$ or U. S. 256) in the lens. It is obvious that there must also be a speed-time for every other stop regardless of whether the unit scale has been applied to the lens or not. Thus in lenses having the U. S. numbers the smallest stop is usually 128 and this stop will show a speed-time half of that for the unit stop which is U. S. 256. This being true the speed-time for any emulsion can be found for the smallest stop or in fact for any other stop in a lens and this speed time divided by the unit actinicity of the subject will give the exposure with that stop and the actinic unit may thus be employed for exposure whether the unit scale has or has not been applied to the lens.

This method is not recommended however except as a gradual means of trying out the unit method.

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